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SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET PERIODICALS

FIAN	Phys. Inst. Acad. Sci. USSR.
GDI	Water Power Inst.
GITI	State Sci.-Tech. Press
GITTL	State Tech. and Theor. Lit. Press
GONTI	State United Sci.-Tech. Press
Gosenergoizdat	State Power Press
Goskhimizdat	State Chem. Press
GOST	All-Union State Standard
GTTI	State Tech. and Theor. Lit. Press
IL	Foreign Lit. Press
ISN (Izd. Sov. Nauk)	Soviet Science Press
Izd. AN SSSR	Acad. Sci. USSR Press
Izd. MGU	Moscow State Univ. Press
LEIIZhT	Leningrad Power Inst. of Railroad Engineering
LET	Leningrad Elec. Engr. School
LETI	Leningrad Electrotechnical Inst.
LETIIZhT	Leningrad Electrical Engineering Research Inst. of Railroad Engr.
Mashgiz	State Sci.-Tech. Press for Machine Construction Lit.
MEP	Ministry of Electrical Industry
MES	Ministry of Electrical Power Plants
MESEP	Ministry of Electrical Power Plants and the Electrical Industry
MGU	Moscow State Univ.
MKhTI	Moscow Inst. Chem. Tech.
MOPI	Moscow Regional Pedagogical Inst.
MSP	Ministry of Industrial Construction
NII ZVUKSZAPIOI	Scientific Research Inst. of Sound Recording
NIKFI	Sci. Inst. of Modern Motion Picture Photography
ONTI	United Sci.-Tech. Press
OTI	Division of Technical Information
OTN	Div. Tech. Sci.
Stroiizdat	Construction Press
TOE	Association of Power Engineers
TsKTI	Central Research Inst. for Boilers and Turbines
TsNIEL	Central Scientific Research Elec. Engr. Lab.
TsNIEL-MES	Central Scientific Research Elec. Engr. Lab.—Ministry of Electric Power Plants
TsVTI	Central Office of Economic Information
UF	Ural Branch
VIESKh	All-Union Inst. of Rural Elec. Power Stations
VNIIM	All-Union Scientific Research Inst. of Meteorology
VNIIZhDT	All-Union Scientific Research Inst. of Railroad Engineering
VTI	All-Union Thermotech. Inst.
VZEI	All-Union Power Correspondence Inst.

Note: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us. — Publisher.

SOME TERNARY SYSTEMS OF WATER – DIOXAN – ELECTROLYTE

Yu.B. Klemenik

A mixture of water and dioxan is one of the most widely used mixed solvents in physicochemical investigations. So, naturally, this binary system has been investigated from many points of view – melting point, vapor pressure, density, surface tension, viscosity, refractive index, heat of mixing [1-3]. The diagrams of density, viscosity and heat of mixing provide evidence of the existence in the system of a chemical compound which, apparently, is a hydrate unstable to heat. But the absence of any indication of this compound from the diagrams of other properties has induced some investigators to doubt the existence of a definite compound between water and dioxan [4, 5].

A number of investigators have successfully developed the idea of using a ternary system, with separation of phases, to elucidate the chemical nature of the binary systems of which the ternary is composed.

Separation of phases in the ternary system water-dioxan-electrolyte (where the electrolyte is HCl, NaCl, LiCl, $LiNO_3$, KCl, etc.) has been noted in the literature [4, 6]. The present paper is an attempt to use some of these systems to elucidate the character of the interaction between the components of the binary system water–dioxan.

EXPERIMENTAL

Dioxan was dried over anhydrous calcium chloride, distilled, cooled to 6-7°, and further dried by distillation from metallic sodium; the fraction distilling in the range 101.1-101.2° was collected. The product had m.p. 11.6°. All the other substances used were of chemically pure grade. Hydrogen chloride was obtained by heating sodium chloride with sulfuric acid and dried by passing it through 95% sulfuric acid.

With regard to the component binary systems of the water–dioxan –hydrogen chloride ternary system, it is known that hydrogen chloride is very soluble in water and also in dioxan [7], that water and dioxan are miscible in all proportions, but that hydrogen chloride causes separation into two liquid phases.

The principal difficulty in the determination of the solubility of hydrogen chloride in mixtures of water and dioxan was that it was impossible to pass a stream of hydrogen chloride over the surface of the liquid without producing a change in the composition of the latter, due to evaporation. For this reason, the hydrogen chloride (shown to be free from air) was only passed through the saturation flask until all the air originally present in the flask had collected in a eudiometer tube over water. At the end of this saturation period, in order to remove any residual air, a further volume of hydrogen chloride equal to three times the volume of the free space over the saturated solution was passed through the flask. The pressure of hydrogen chloride in the apparatus was controlled using a manometer. The content of hydrogen chloride in weighed samples of the saturated solution was determined, after dilution, by titration with alkali to the end point of methyl orange. The solubility of hydrogen chloride was measured three times for each water–dioxan mixture. The differences between separate determinations did not excede 0.3%.

Mean values obtained for the solubility of hydrogen chloride in water–dioxan mixtures at atmospheric pressure (25°) are shown in Table 1.

Solubility isotherms, derived from these data, are shown in Figure 1. It is clear that separation into two liquid phases does not occur with any of the solutions saturated with hydrochloric acid. The region of separation is of the closed loop type. The boundaries of this region were determined by titration of a mixture within this region until two layers no longer existed. Solutions, corresponding to points lying to the left of the line joining dioxan to the point d, were prepared by mixing dioxan, water and hydrogen chloride in different proportions. The right hand boundary was then determined by titration of two phase mixtures with solutions of hydrogen chloride in dioxan. Similarly, the left hand boundary was determined by titration with mixtures of water and dioxan. The composition of the initial mixture and the quantity of solution added were checked by weighing (calculating from the specific gravities of the solutions used). The composition of each solution corresponding to a point on the boundary isotherm, was determined three times. The differences between separate determinations did not excede 0.3%. Table 2 gives the mean values of the compositions of these solutions.

TABLE 1
The $H_2O-C_4H_8O_2-HCl$ System

Composition of solutions saturated with hydrogen chloride (mole %).		
H_2O	$C_4H_8O_2$	HCl
74.3	0	25.7
55.6	14.3	30.1
42.5	23.0	34.5
30.2	31.0	38.8
22.2	37.8	40.0
11.3	47.2	41.5
0	56.0	44.0

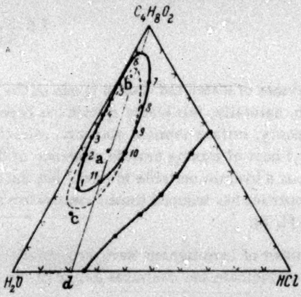

Fig. 1. Solubility diagram for the system water–dioxan–hydrogen chloride
Explained in the text.

The boundary isotherm drawn from this data is shown in Fig. 1 (the number of the solution corresponds to the number of the point on the isotherm). In the upper part of the two phase region it is the lower layer that gradually diminishes on movement outwards, and vanishes as the boundary is crossed. In the lower part of the region it is the upper layer that diminishes and finally disappears. At points 3 and 9 separation occurs instantly into two layers of nearly equal volume for a small change in composition, corresponding to passage through the boundary isotherm.

TABLE 2
The $H_2O-C_4H_8O_2-HCl$ System

No. of Solution	Composition of solution corresponding to the boundary of the heterogeneous region (mole %)		
	H_2O	$C_4H_8O_2$	HCl
1	59.6	33.5	6.9
2	49.8	46.6	3.6
3	44.0	53.6	2.4
4	35.0	63.4	1.6
5	23.1	76.0	0.9
6	10.5	87.7	1.8
7	12.0	76.4	11.6
8	18.9	66.9	14.2
9	27.0	56.6	16.4
10	35.1	47.8	17.1
11	50.5	35.6	13.9

Analysis showed that the main component of the upper layer was dioxan. At the point a (molecular composition $H_2O : C_4H_8O_2 : HCl = 40.4 : 49.0 : 10.6$) the upper layer at 25° occupied 40% of the total volume. The relative concentrations of hydrogen chloride (determined by analysis) in the upper and lower layers were 1:13.4. The melting point of the upper layer was 9.4°. At the point b (molecular composition $H_2O : C_4H_8O_2 : HCl = 17.6 : 78.6 : 3.8$) the upper layer at 25° occupied 90% of the total volume. The relative concentrations of hydrogen chloride in the upper and lower layers were 1:19.7. The melting point of the upper layer was 9.12°. These results confirm that the separation of the system into two layers has the character of a salting out of dioxan by hydrogen chloride.

On heating any of the two phase mixtures, the upper layer increased in volume at the expense of the lower layer.* Thus, heating a mixture corresponding to the point b caused a diminution of the lower layer. The latter vanished at 127°. With a mixture corresponding to a the upper layer already occupied the greater part of the volume at 100°. With a solution corresponding to 1 (a critical point at 25°) warming caused an upper layer to appear, occupying 28% of the volume at 130°.[*] At the point c (molecular composition $H_2O : C_4H_8O_2 : HCl = 67.3 : 23.3 : 9.4$) an upper layer began to form at 140°. Upon a rise in temperature the boundary isotherm was displaced in the direction of greater water content. The position of the isotherm at 100° is shown in Fig. 1 by a dotted line.

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* All experiments above room temperature were done in sealed tubes by the variable temperature method.

It was not possible to draw the boundary of the two phase region sufficiently accurately at much higher temperatures, nor to find the upper ternary critical point. On heating the mixture corresponding to a, the lower layer diminished and vanished at approximately 200°. On heating above 200° and subsequently cooling, the previous distribution of layers was not restored, and, often, separation into two layers did not occur. Repeated heating–not above 160-170° gave completely reproducible separation into layers.

A similar dependence of separation into two layers on temperature was found for the ternary systems water–dioxan –lithium chloride and water–dioxan–potassium chloride. Thus, with a mixture of composition $H_2O : C_4H_8O_2 : LiCl = 70.5 : 26.6 : 2.9$, the upper layer was 9.1% of the total volume at 25° and 47% at 95°. A ternary mixture of the composition $H_2O : C_4H_8O_2 : KCl = 69.6 : 28.8 : 1.6$ was homogeneous at normal temperature. Separation, with formation of an upper layer, only occurred at 70°. With these solutions, the melting point of the upper layer, separated at the higher temperature, was never less than 7°. Clearly, the main component of the upper layer was dioxan.[**]

With regard to the ternary system water–dioxan–sulfuric acid, it is known that the components are completely miscible in the binary systems water–dioxan and water–sulfuric acid; in the system dioxan – sulfuric acid a fairly stable complex $C_4H_8O_2 \cdot H_2SO_4$ is formed, with a melting point of 101° [8]. The boundary of the heterogeneous region (crystalline complex of dioxan with sulfuric acid and its saturated solution) was determined for this system, at 25°, by the titration method. The composition of the solution, corresponding to the point nearest to the H_{20} vertex, was found by adding water to a mixture of dioxan and sulfuric acid. The compositions of the solutions, corresponding to the other points on the boundary, were found by adding dioxan to aqueous solutions of sulfuric acid. Some difficulty was experienced in these determinations because the crystalline complex dissolved very slowly in nearly saturated solutions (concentrated solutions of the complex were highly viscous). For this reason, the solutions were heated gently – not above 35°, and then cooled and seeded with the crystalline complex. The composition of each solution, corresponding to a point on the boundary of the heterogeneous region, was determined three times. Differences between separate determinations did not excede 0.4% (for the composition by weight of dioxan in the mixture). Table 3 gives the results obtained. The heterogeneous region is shown graphically in Fig. 2.

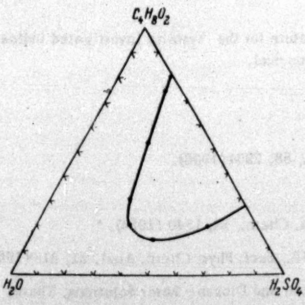

Fig. 2. Solubility diagram for the system water–dioxan–sulfuric acid

Addition of sulfuric acid to water–dioxan mixtures of various compositions (mixtures were taken with molecular ratios of water to dioxan 1:9, 2:8, 3:7, 4:6, 5:5, 6:4, 7:3, 8:2 and 9:1) did not produce separation. With a rise in temperature the boundary of the heterogeneous region contracted. Its limit lay at the midpoint of the dioxan–sulfuric acid side at a temperature of 101° (the melting point of the pure complex).

A noteworthy feature of the above data on ternary systems is the dependence of separation into two phases on temperature. In the absence of a definite chemical compound between water and dioxan, it would be expected that the salting out effect would decrease with a rise in temperature. But, in fact, the reverse happens. With a rise in temperature the upper layer of dioxan increases. A similar type of dependence on temperature has been described in the literature for phase separation in the system water–dioxan–lithium nitrate [4]. In the water–dioxan–hydrogen chloride system, for points lying below the separation isotherm at 25° (in the direction of the H_2O vertex), separation of phases only begins at elevated temperatures.

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[*] Graduated tubes were used to determine the relative volumes of the upper and lower layers at higher temperatures.

[**] The systems containing potassium and lithium chlorides were only of interest in connection with the dependence on temperature of the relative volumes of the upper and lower layers. The two phase regions were not investigated systematically.

TABLE 3

The $H_2O-C_4H_8O_2-H_2SO_4$ System

Composition of solutions corresponding to the boundary of the heterogeneous region (mole %).

H_2O	$C_4H_8O_2$	H_2SO_4
5.8	73.8	20.4
22.6	52.9	24.5
40.2	30.7	29.1
46.4	20.2	33.4
41.1	14.0	44.9
18.0	19.7	62.3

There is a universal rule enunciated by V. F. Alekseev, according to which the existence in a system of a lower critical point of phase separation is evidence of the formation of a thermally unstable compound, in most cases a hydrate [9]. The complexity of the processes, controlling phase separation in the ternary systems investigated, makes it difficult to identify the components whose interaction is responsible for the variation with temperature of phase separation in these systems. But the fact that the nature of this variation is the same for all the systems investigated, although the third components – KCl, LiCl, $LiNO_3$ and HCl – differ markedly in their solubilities in water and especially in dioxan, strongly suggests that the water–dioxan system is the controlling factor.

In the system water–dioxan–hydrogen chloride, as the temperature rises, a considerable part of the separation isotherm approaches close to the water–dioxan side. This shift of the separation isotherm is characteristic of ternary systems containing a binary system with a considerable tendency to separation [10]. In this case, it clearly provides evidence of an appreciable tendency to separation in the water–dioxan system, which may be attributed to increased thermal dissociation of dioxan hydrate with increasing temperature. Phase separation in the water–dioxan–sulfuric acid system may be explained by the powerful interaction between dioxan and sulfuric acid (formation of a complex).

The author wishes to thank O. A. Osipov and Ya. F. Mezhenny for their valuable advice.

SUMMARY

1. An investigation has been made of the ternary systems water–dioxan–hydrogen chloride and water–dioxan–sulfuric acid, and a few points have been determined for the ternary systems water–dioxan–lithium chloride and water–dioxan–potassium chloride.

2. It was found that the region of phase separation in the system water–dioxan–hydrogen chloride has the form of a closed loop, which vanishes at an upper ternary critical point. The phase diagram of the system water–dioxan–sulfuric acid at normal temperature is composed of a large area of homogeneous solutions, with a heterogeneous region adjacent to the dioxan–sulfuric acid side.

3. The nature of the variation of phase separation with temperature for the systems investigated indicates the existence in the water–dioxan system of a thermally unstable compound.

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INVESTIGATION OF THE INTERACTION OF PHENYL –AND DIPHENYL – UREAS WITH ORGANIC ACIDS BY THE METHOD OF PHYSICOCHEMICAL ANALYSIS

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In a previous investigation of the interaction between ureas and carboxylic acids [1] it was shown that molecular compounds whose stability depends, to a considerable extent, on the structure of the acid are formed. It was found that replacement of one of the amino groups in the urea molcule by methyl (acetamide) strengthened the interaction with aliphatic acids [2].

The object of the present investigation was to investigate the effect of introducing one or two phenyl groups into the urea molecule upon its chemical interaction with acids. The results are presented of the investigation of 14 binary systems of phenyl- and diphenyl– ureas with acetic, n-butyric, n-caproic, chloroacetic, trichloroacetic, benzoic and salicylic acids.

The investigation was carried out by the method of physicochemical analysis; the melting points, densities, viscosities and electrical conductivities of the mixtures were determined. The experimental method has been described previously [3]. In addition, the ultraviolet absorption spectra were investigated, both of the individual components and the corresponding mixtures. In analyzing the absorption curves of two component mixtures it was assumed that the experimental curves (shown in the Figures as continuous lines), in the absence of chemical interaction between the components, should coincide with curves calculated on the basis of Beer's law (shown in the Figures as dotted lines). Noncoincidence of the curves was taken as evidence of chemical interaction.

The absorption spectra were measured with an SF-4 spectrophotometer. Water distilled three times was used as solvent. The concentrations of the working solutions used for the spectroscopic measurements were as follows: acetic acid 0.05 M, n-butyric acid 0.05 M, n-caproic, chloroacetic, trichloroacetic, benzoic and salicylic acids 0.01 M. The working solution of phynylurea was prepared by diluting 2.5 ml of saturated solution to 100 ml (at 17.5°) and of diphenylurea by twofold dilution of the solution saturated at 17.5°. Solutions of mixtures were prepared by mixing equal volumes of aqueous solutions of the components, whose concentrations were double those of their working solutions. The acids were purified as described previously, and had the same physical constants [1, 2]. Phynylurea and symmetrical diphenylurea were synthesized from aniline hydrochloride and urea [4]. Phenylurea had m.p. 147° after several recrystallizations from water, and symmetrical diphenylurea had m.p. 235° after two recrystallizations from alcohol.

To check the validity of Beer's law and the absence of disturbing effects the variation of light absorption with concentration was investigated for each of the components. For phenylurea the concentration was varied from 0.5 c to 3 c (where c is the working concentration), for diphenylurea from 0.75 c to 3 c, for acetic, n-butyric, chloroacetic and trichloroacetic acids from 0.75 c to 4 c, for benzoic and salicylic acids from 0.5 c to 3.5 c. Extinction coefficients, calculated for the long wave absorption bands of each of the components, were found to have constant values, independent of concentration.

Systems With Acetic Acid

Figure 1 shows results obtained for the system acetic acid ---phenylurea. The melting point curve consists of two branches, intersecting at the eutectic point (90 mole % acetic acid, 3°). The density and viscosity curves, obtained at 110°, like the melting point curve, do not provide evidence for chemical interaction; the electrical conductivity curves at 110, 120 and 130° pass through maxima at about 75 mole % of acetic acid. Decomposition of the mixture began above 110°, and the bubbles of gas evolved blocked up the capillary of the viscometer, so that it was not possible to measure the viscosity. This decomposition caused a gradual increase in electrical conductivity. The conductivity curves shown in Fig. 1 were obtained 15 minutes after immersion in the thermostat. After longer immersion the absolute values of the conductivities increased, but the shape of the curve did not alter.

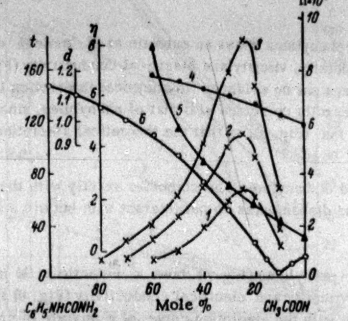

Fig. 1. The phenylurea – acetic acid system. Specific electrical conductivities at temperatures – 1) 110°, 2) 120°, 3) 130°; 4) density at 110°; 5) viscosity at 110°; 6) melting point curve.

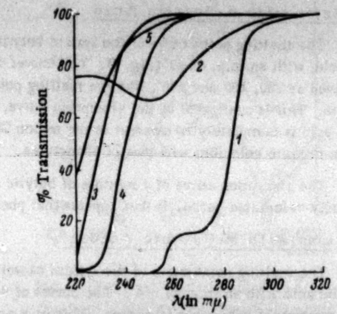

Fig. 2. Transmission curves of solutions. 1) $C_6H_5NHCONH_2$, 2) $C_6H_5NHCONHC_6H_5$, 3) CH_3COOH, 4) CCl_3COOH, 5) n-$C_5H_{11}COOH$.

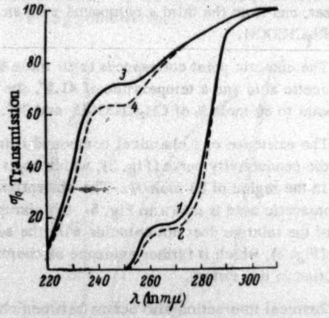

Fig. 3. Transmission curves of solutions.
1) $CH_3COOH + C_6H_5NHCONH_2$,
2) additive; 3) $CH_3COOH +$
$+ C_6H_5NHCONHC_6H_5$, 4) additive.

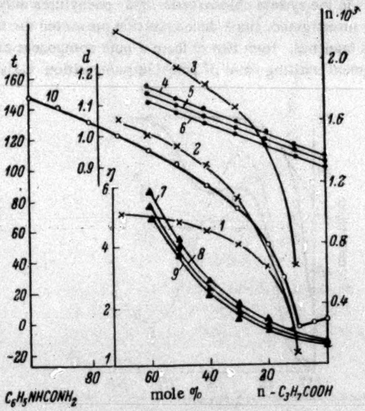

Fig. 4. The phenylurea – n-butyric acid system. Specific electrical conductivities at temperature – 1) 110°, 2) 130°, 3) 140°; densities at temperatures – 4) 120°, 5) 130°, 6) 140°; viscosities at temperatures – 7) 120°, 8) 130°, 9) 140°; 10) melting point curve.

Absorption curves for solutions of phenylurea and acetic acid are shown in Fig. 2. In Fig. 3. are shown the absorption curve of a mixture of acetic acid and phenylurea and the theoretically calculated addition curve. As is evident from the trace, they do not coincide. This fact, together with the existence of a maximum in the conductivity isotherm, suggests that interaction between the components occurs in this system.

Investigation of systems of diphenylurea with acetic acid, or any of the other acids, by the method of physicochemical analysis was not possible, since the mixtures decomposed strongly on heating. Only the absorption spectra of the aqueous solutions were investigated. The absorption curve of diphylurea is shown in Fig. 2. In Fig. 3 are shown the real and theoretical absorption curves for a mixture of acetic acid and diphenylurea, which do not coincide. The difference between the curves in the region of 260 mμ amounts to 7-8%, which indicates chemical interaction between acetic acid and diphenylurea.

Systems with n-Butyric Acid

The melting point curve of the system butyric acid–phenylurea shows an eutectic at 91 mole % of butyric acid, with an m.p. of –7° (Fig. 4). The curves dor the density, visosity and electrical conductivity (Fig. 4), observed at 120, 130 and 140°, like the melting point curve, show no evidence for chemical interaction in this system. This is confirmed by the absorption curve, which exactly coincides with that of phenylurea, since butyric acid is completely transparent in the region 250-320 mμ (Fig. 5), so that the theoretical absorption curve of the mixture coincides with that of phenylurea.

The absorption curve of a mixture of butyric acid and diphenylurea also coincides exactly with the theoretically calculated curve. It thus appears that phenyl– and diphenylurea do not interact with butyric acid.

Systems with n-Caproic Acid.

The melting point curve of the system caproic acid – phenylurea (Fig. 6) shows a eutectic at 90 mole % caproic acid with an m.p. of – 4°. The curves of density, viscosity and electrical conductivity (Fig. 6) show no indication of compound formation. This is in agreement with the absorption curve of a mixture of caproic acid and phenylurea, which exactly coincides with that of phenylurea, since caproic acid is 100% transparent in this region. The real absorption curve of a mixture of caproic acid and diphenylurea coincides exactly with the calculated curve.

Systems with Chloroacetic Acid

In the system chloroacetic acid–phenylurea only the melting point and electrical conductivity at 120° were investigated, since decomposition prevented the measurement of viscosity. The melting point curve has three branches; from two of these a pure component crystallizes, and from the third a compound witn an incongruent melting point of probable composition $C_6H_5NHCONH_2ClCOOH$.

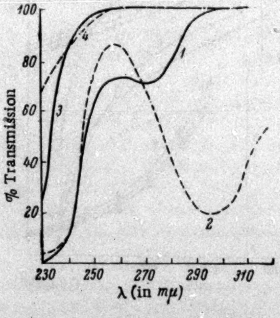

Fig. 5. Transmission curves of solutions. 1) C_6H_5COOH, 2) o-$C_6H_4(OH)COOH$, 3) C_3H_7COOH, 4) $CH_2ClCOOH$.

The eutectic point corresponds to 80 mole % of chloroacetic acid and a temperature of 41.5°, the transition point to 50 mole % of $CH_2ClCOOH$ and 70°.

The existence of a chemical compound is indicated by the conductivity curve (Fig. 7), which has a maximum in the region of 50 mole %. The absorption curve of chloroacetic acid is shown in Fig. 5; the absorption curve of the mixture does not coincide with the additive curve (Fig. 8), which is further evidence of chemical interaction in this system.

Chemical interaction also occurs between chloroacetic acid and diphenylurea, as is indicated by the noncoincidence of the real and calculated absorption curves of the mixture (Fig. 8).

Systems with Trichloroacetic Acid

In the system trichloroacetic acid–phenylurea, as in the preceding system, only melting point and electric conductivity were investigated. The melting point curve indicates the existence of a compound with an incongruent melting point of probable composition $C_6H_5NHCONH_2 \cdot CCl_3COOH$. The eutectic mixture contains 80 mole % of trichloroacetic acid and has an m.p. of 34°; the transition point lies at 50 mole % of CCl_3COOH and a temperature of 71.5°. The electrical conductivity isotherm at 125° passes through a maximum in the region of 50 mole %.

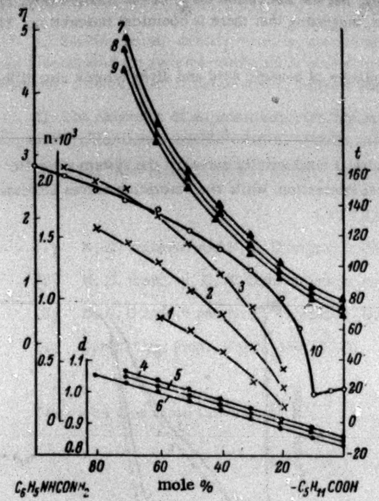

Fig. 6. The phenylurea – n-caproic acid system. Specific electrical conductivities at temperatures: 1) 120°, 2) 130°, 3) 140°, densities at temperatures: 4) 120°, 5) 130°, 6) 140°, viscosities at temperatures: 7) 120°, 8) 130°, 9) 140°; 10) melting point curve.

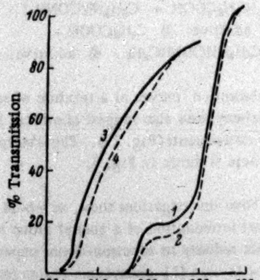

Fig. 9. Transmission curves of solutions. 1) $CCl_3COOH + C_6H_5NHCONH_2$; 2) additive; 3) $CCl_3COOH + C_6H_5NHCONHC_6H_5$. 4) additive.

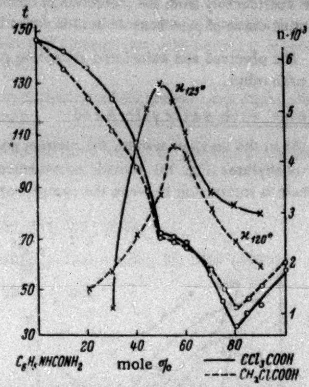

Fig. 7. Melting point and electrical conductivity in the systems phenylurea – chloroacetic acid and phenylurea – trichloroacetic acid.

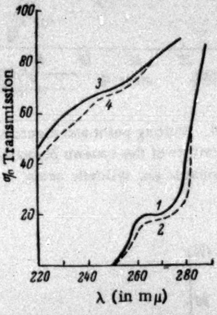

Fig. 8. Transmission curves of solutions. 1) $CH_2ClCOOH + C_6H_5NHCONH_2$, 2) additive; 3) $CH_2ClCOOH + C_6H_5NHCONHC_6H_5$ 4) additive.

The absorption curve of trichloroacetic acid is shown in Fig. 2; the experimental and theoretical absorption curves of the mixture are shown in Fig. 9. The noncoincidence of the curves indicates chemical interaction.

In Fig. 9 are shown the absorption curves of a mixture of trichloroacetic acid and diphenylurea, which also indicate chemical interaction.

Systems with Benzoic Acid

The melting point and electrical conductivity curves of the system benzoic acid – phenylurea give no indication of the existence of chemical interaction (Fig. 10). But the absorption curve of the mixture (Fig. 11) differs considerably from the theoretically calculated curve, suggesting that there is chemical interaction. The absorption curve of pure benzoic acid is shown in Fig. 5.

The observed and calculated absorption curves of a mixture of benzoic acid and diphenylurea also differ from each other.

Systems with Salicylic Acid

As in the previous system, the melting point and electrical conductivity curves of the system salicylic acid – phenylurea (Fig. 10) provide no evidence of chemical interaction, while the absorption curves indicate that there is interaction between the components (Fig. 12).

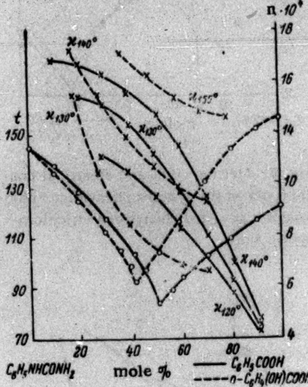

Fig. 10. Melting point and electrical conductivity of the systems phenylurea with benzoic and salicylic acids.

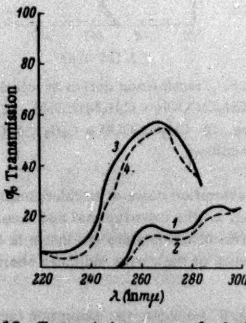

Fig. 12. Transmission curves of solutions. 1) $o\text{-}C_6H_4(OH)COOH + C_6H_5NHCONH_2$; 2) additive; 3) $o\text{-}C_6H_4(OH)COOH + C_6H_5NHCONHC_6H_5$; 4) additive.

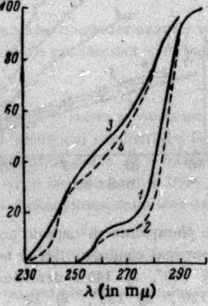

Fig. 11. Transmission curves of solutions. 1) $C_6H_5COOH + C_6H_5NHCONH_2$; 2) additive. 3) $C_6H_5COOH + C_6H_5NHCONHC_6H_5$. 4) additive.

The absorption curves of a mixture of salicylic acid with diphenylurea also suggest chemical interaction between the components (Fig. 12). The absorption curve of salicylic acid is shown in Fig. 5.

The above investigations show, as would have been expected, that introduction of a phenyl group into the urea molecule reduces its electron-donor capacity. In comparison with urea [1], phenylurea reacts less vigorously with acetic acid. With an increase in length of the acid radical chemical interaction diminishes. Introduction of chlorine, which increases the dissociation of acetic acid, produces a stronger interaction with phenyl- and diphenylureas. The results obtained with aromatic acids are somewhat unexpected. It might have been anticipated that the introduction of an aromatic nucleus, and particularly the introduction of a hydroxyl group (salicylic acid) would have increased the tendency of the acid to interact with phenyl- and diphenylureas. But, in fact, this is not so; inteaction between components in these systems is only revealed by the absorption curves.

SUMMARY

1. Melting point, density, viscosity, electrical conductivity and absorption spectra in aqueous solution have been investigated for systems composed of phenylurea and symmetrical diphenylurea with acetic, n-butyric, n-caproic, chloroacetic, trichloroacetic, benzoic and salicylic acids.

2) The existence of an intermolecular interaction has been demonstrated for phenyl- and diphenylureas with acetic, chloroacetic, trichloroacetic, benzoic and salicylic acids.

3) It has been established that phenyl- and diphenylureas do not react with n-butyric and n-caproic acids.

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CATALYSIS OF THE VAPOR PHASE HYDROLYSIS OF HALOGEN DERIVATIVES OF ORGANIC COMPOUNDS

II. REVERSABILITY OF THE VAPOR PHASE HYDROLYSIS OF CHLOROBENZENE REACTION

A.I. Naumov and E.I. Geidelberg.*

The vapor phase hydrolysis of arylhalides, particularly of chlorobenzene, has been studied by a number of investigators [1]; there is not however, one paper devoted to the study of the reverse reaction of esterification. Reference is made to this reverse process in two publications. In the first of these [2] it is stated that the possibility of the existence of a dynamic equilibrium in the vapor phase hydrolysis of chlorobenzene is not supported by experiment. In the second [3] it is noted that chlorobenzene was obtained in 2.1% yield from a 23% solution of HCl and phenol. We have attempted to investigate the catalytic vapor phase esterification of hydroxy derivatives of aromatic hydrocarbons with a series of hydrogen halide acids, considered as a separate reaction. Some results were obtained on the interaction of hydrogen chloride and phenol from which it was possible to calculate equilibrium constants for the reversible reaction

$$C_6H_5Cl + H_2O \rightleftarrows C_6H_5OH + HCl$$

All the experiments were made in the presence of a phosphate catalyst, which we have found to be the most active and selective of known contact catalysts. Special experiments showed that, under these conditions, hydrolysis of chlorobenzene took place on an internal active region of the catalyst. Investigations of the speed of reaction of phenol with hydrogen chloride were made with fresh samples of the same catalyst. The total duration of each experiment was 3 hours; the catalyzate was collected under fixed conditions for the last 2 hours. The experimental results are shown in Table 1.

TABLE 1

Dependence of the Rate of Formation of Chlorobenzene on the Concentration of Hydrogen Chloride

Initial concentration of HCl (in mole fraction)	Time of contact (in sec)	Degree of conversion of HCl (%)	Rate of formation of chlorobenzene g/liter/hr.
0.200	1.24	37.2	200
0.206	0.736	18	167
0.206	1.47	42.4	197
0.194	1.39	40.9	190
0.135	1.33	62.6	211
0.137	0.85	35.3	190
0.083	0.60	41.2	191
0.081	1.09	79.5	197
0.052	0.66	78.4	185

TABLE 2

Hydrolysis of Chlorobenzene at 470°

Initial concentration of chlorobenzene (in mole fraction	Time of contact (in sec)	Degree of conversion of chlorobenzene (%)	Rate of formation of phenol (g/liter per hour).
0.130	0.611	25.6	150
0.153	0.673	24.6	154
0.147	0.678	23.9	143

For comparison, the results of three experiments on the hydrolysis of chlorobenzene on the same catalyst, under the same conditions, are shown in Table 2.

From a comparison of the data in Tables 1, and 2, it is clear that, under the same conditions, the rate of formation of chlorobenzene from hydrogen chloride and phenol is greater than that of phenol from chlorobenzene and water. These results suggest that other esterification reactions, of hydroxy derivatives of aromatic hydrocarbons with various hydrogen halide acids, might also be carried out catalytically in the vapor phase. Further, from the data in Table 1, it appears that the rate of esterification remains practically constant for a fourfold variation in the concentration of hydrogen chloride, so that, under these conditions, the reaction is nearly of the order of zero with respect to HCl. The esterification of phenol can be recommended as a laboratory method for obtaining chlorobenzene completely free from polychloro derivatives.

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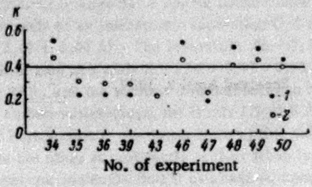
* With the assistance of L. V. Chubarov.

There are considerable experimental difficulties in investigating the equilibrium of the reaction. On the one hand, equilibrium is not established quickly, and, on the other hand, it is no use prolonging the time of contact, since the occurrence of side reactions interferes with the calculations. For this reason, equilibrium was investigated by selecting concentrations of all the components calculated to be near their equilibrium concentrations; then, with a contact time of about 6 seconds, there was very little reaction, but it was only necessary to find out its direction. The absence of any marked heat of reaction made it possible to work with 500 ml of catalyst, which allowed the analyses to be made with sufficient accuracy. The duration of each experiment was 3 hours, and the catalyzate was collected under fixed conditions for the last 2 hours. The reproducibility of the results was adequate. In each experiment, not only were the concentrations determined in the feed and the product, but a material balance was made (the latter approximated to 100%). The experimental results are shown in Table 3 and in the figure.



Equilibrium constant of the esterification reaction (K).
1) Initial mixture; 2) Catalyzate.

It is clear from the data in Table 3 that the most probable value of the equilibrium constant is within the range 0.38 - 0.39. If the ratio [C_6H_5OH] [HCl] : [C_6H_5Cl] [H_2O] in the feed is less than 0.39, the reaction noticeably proceeds in the direction of hydrolysis (experiments 2-4, 7•), if it is greater the reaction proceeds in the direction of esterification (experiments 1, 6,••8, 9).

EXPERIMENTAL

The catalyst was prepared from calcium chloride and cupric chloride by precipitation with diammonium phosphate and ammonia. Its total content of $CuCl_2$ was 0.8% by weight. Before use, the catalyst was conditioned to the vapor phase hydrolysis reaction for 10 hours at 470°, with two revivifications by air at the same temperature. This conditioning was found to be necessary to avoid error in the assessment of the direction of the reaction; in the first few hours the catalyst irreversibly absorbed hydrogen chloride to an appreciable extent.

TABLE 3
Determination of the Equilibrium Constant of the Esterification Reaction
(Temperature 470°; contact time 5-7 seconds).

No. of experiment	Composition (mole %)								$\frac{[C_6H_5OH] [HCl]}{[C_6H_5Cl] [H_2O]}$	
	Feed				catalyzate					
	C_6H_5OH	C_6H_5Cl	HCl	H_2O	C_6H_5OH	C_6H_5Cl	HCl	H_2O	feed	catalyzate
1	0.253	0.121	0.127	0.498	0.233	0.130	0.126	0.512	0.536	0.445
2	0.245	0.115	0.060	0.583	0.248	0.111	0.076	0.560	0.22	0.306
3	0.254	0.120	0.058	0.560	0.255	0.106	0.071	0.567	0.22	0.288
4	0.223	0.108	0.000	0.668	0.258	0.081	0.041	0.622	—	0.210
5	0.084	0.041	0.178	0.696	0.072	0.041	0.176	0.710	0.527	0.433
6	0.133	0.145	0.122	0.599	0.140	0.136	0.137	0.587	0.187	0.232
7	0.215	0.089	0.119	0.577	0.208	0.097	0.108	0.587	0.500	0.395
8	0.199	0.082	0.121	0.598	0.194	0.091	0.119	0.596	0.492	0.428
9	0.193	0.094	0.121	0.593	0.197	0.112	0.123	0.568	0.416	0.380
10	0.195	0.107	0.120	0.590	0.195	0.108	0.124	0.572	0.370	0.388

• Probably should read 6 - Publisher's note.

• • Probably should read 7 - Publisher's note.

The experiments were carried out with the reactants flowing through a quartz tube, supported in an electrically heated tube furnace. The temperature of the whole bed of catalyst was kept constant within ± 1.0°. The dosage of the reagents was automatically maintained constant within ± 1.5%. The reagents used for preparing the catalyst and the feed were of chemically pure grade.

Analysis of the catalyzate. Phenol was determined by Koppeschaar's method [4]; HCl by titration with alkali; chlorobenzene directly, by separation from the alkali-washed catalyzate, drying and weighing; water by difference.

SUMMARY

The reaction between phenol and hydrogen chloride has been investigated in the vapor phase in the presence of a phosphate catalyst. It has been shown that this reaction proceeds faster than the hydrolysis of chlorobenzene to phenol (under the same conditions). The equilibrium constant of the esterification reaction has been determined experimentally for the first time.

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X-RAY STRUCTURAL INVESTIGATION OF ORGANOMETALLIC COMPOUNDS

STEREOCHEMISTRY OF FERROCENE AND ITS DERIVATIVES

Yu. T. Struchkov

Geometry of the ferrocene molecule. The full x-ray structural investigation of ferrocene by construction of a three dimensional set of electron densities was performed by Dunitz and Ogrel [1]. These authors demonstrated a "sandwichlike" center of symmetry in the structure of the ferrocene molecule (Fig. 1).

As the result of aromatization, i.e. the established equivalence of all the bonds in the five-membered rings, each C–C linkage has a double bound character of 0.4; and, according to the empirical curve of Pauling, this corresponds to an interatomic separation C-C equal to 1.41 A, practically identical with the result of x-ray analysis (1.40 ± 0.04 A). The separation Fe – C, $2.04_4 \pm 0.02_4$ A, is equal to the sum of the covalent single bond radii of iron and carbon – 1.26 + 0.77 = 2.03 A. The separation between the planes of the five-membered rings is 3.33 A, and the shortest distance between carbon atoms of different rings is 3.41 A. The molecular radius of carbon varies within the limits 1.7 -1.8 A, so that the C – C distance between the rings in the ferrocene molecule corresponds to the lower limit of this radius; the five-membered rings in the ferrocene molecule lie one above the other as compactly as the carbon lattices in graphite. The iron atom is "squeezed" so tightly into the ferrocene molecule that it can have no contact with surrounding molecules, and the volume of the ferrocene molecule is equal to that of two cyclopentadienyl residues. The ferrocene "sandwich" is like a cylinder of height $3.33 + 2R_C = 6.6$ A and radius $1.20 + \frac{1.70 + 1.08 + 1.20}{2} = 3.1$ A, with an equatorial "trough" 1.4 A high and 0.3 - 0.4 A deep. This "trough" is created by the protruding hydrogen atoms (Fig. 2).

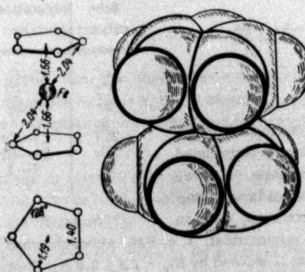


Fig. 1.

Quantum mechanical calculations, by the method of molecular orbitals [2], show that rotation of one-five-membered ring in the ferrocene molecule with respect to the other, about the axis of symmetry of the ring, must be "free," so that the energy of interaction between Fe – C does not depend on the relative orientation of the rings. However, the normal steric interaction of the carbon atoms of the different rings must favor the antiparallel, centrally symmetric configuration, which is, indeed, found in the ferrocene crystal. Calculation of the steric interaction leads to the potential curve shown in Fig. 3. Here the energy, U, and the angle of relative orientation, ω, are 0.72 and 144° respectively for a parallel configuration of the rings, and 36 and 108°

for an antiparallel configuration (the period of the curve is 72° = 360°/5). The minimum potential of the curve corresponds to an antiparallel orientation, the maximum to a parallel orientation with the shortest C – C distance between rings of 3.33 A, indicating a small compression of the carbon atoms equal to $\frac{3.41 - 3.33}{2} = 0.04$ A.

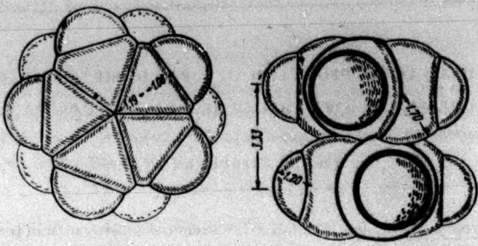


Fig. 2.

Thus internal rotation in the ferrocene molecule is restricted and not completely free, the potential barrier for rotation being higher than with ethane, but somewhat less than with biphenyl (see below). Relative rotation of the rings in the vapor and in solution has been established by electron density investigations of ferrocene [8] and dipole moment measurements of diacetylferrocene [3] and di-p-chlorophenylferrocene [4]. In the crystal, rotation is inhibited, and the rings have a definitely fixed mutual orientation. However the electron density configuration [1] shows that, even in the crystal, the rings oscillate around their axes with appreciable amplitude, although their time average configuration is found to be centrally symmetrical.

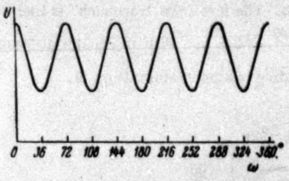


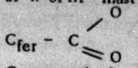
Fig.3.

Stereochemistry of ferrocene derivatives with internal rotation. The introduction into the ferrocene molecule of one or two (in different rings) simple substituents somewhat increases the steric resistance to free rotation, as is evident from the following Table.

Substituent	Separation shortened	Sum of intramolecular radii Σ (A)	Shortening Δ = Σ−3.33 (A)
—	C—C	1.70 + 1.70 = 3.40	0.07
Cl	C—Cl	1.70 + 1.80 = 3.50	0.17
Br	C—Br	1.70 + 1.95 = 3.65	0.32
I	C—I	1.70 + 2.10 = 3.80	0.47
2Cl	Cl—Cl	1.80 + 1.80 = 3.60	0.27
2Br	Br—Br	1.95 + 1.95 = 3.90	0.57
2I	I—I	2.10 + 2.10 = 4.20	0.87

However, the potential barrier corresponding to the compression even though fairly large is surmounted by thermal vibrations at normal temperature. It is well-known that with diphenyl, in the vapor or in solution, there is mutual rotation of the benzene rings, while in the crystal, the molecule is centrally symmetrical, i. e. flat, although, when the two rings are coplanar, the separation between the o-carbon atoms is reduced by $2R_C - 2.9 = 0.6$ A. Another example is the o,o'-dichlorobenzidine molecule [5]. In the crystal this molecule is not coplanar, and the angle between the planes of the benzene rings is about 70°. At the same time, isomerism of the diphenic acid type is not observed with this substance, although on complete rotation the separation Cl–Cl is ostensibly reduced to 1.2 A instead of $2R_{Cl} = 3.6$ A (in reality the reduction is much less, since, at the instant when one chlorine atom passes the other, there is undoubtedly a distortion of the valency angle, which reduces the compression).

Introduction into the ferrocene molecule of one phenyl substituent, or two in different rings, does not prevent relative rotation of the five-membered rings. Calculation shows that of two different orientations of the phenyl substituent – in the plane of the five-membered ring and perpendicular to it – the most satisfactory sterically is the coplanar arrangement of the five and six-membered rings (the spatial restriction on this is somewhat less than in the diphenyl molecule). For this reason, a phenyl group attached to one five-membered ring does not affect the other, and two phenyl groups attached to different rings affect each other very slightly.

Carboxyl and ester groups in the ferrocene molecule can also be coplanar with the five-membered ring; this is also true for the keto group (in all cases the radical R or Ar must be turned out of the plane of  $C_{fer} - C\overset{\diagup O}{\underset{\diagdown\!\!= O}{}}$ by rotation around the normal bond). Consequently the corresponding mono– and disubstituted ferrocenes (the latter with the substituents in different rings) can show relative rotation of the five-membered rings. But, it is different if the phenyl substituent itself has one or two substituents in the ortho position (or rather two ortho substituents). From the number of compounds of this type which have been synthesized, di-o-tolylferrocene, di-o-nitrophenylferrocene and di-o-carboxyphenylferrocene, may be selected [6] (Fig. 4).

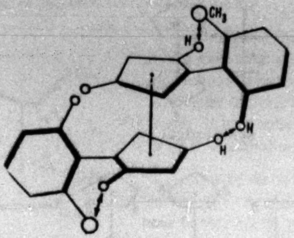
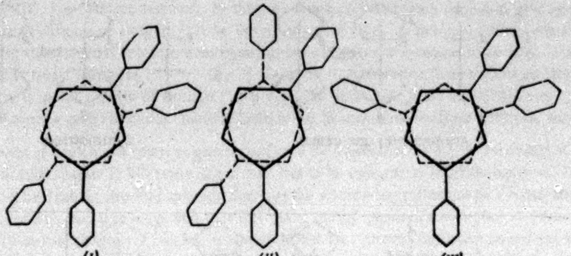


Fig. 4.



(I) (II) (III)

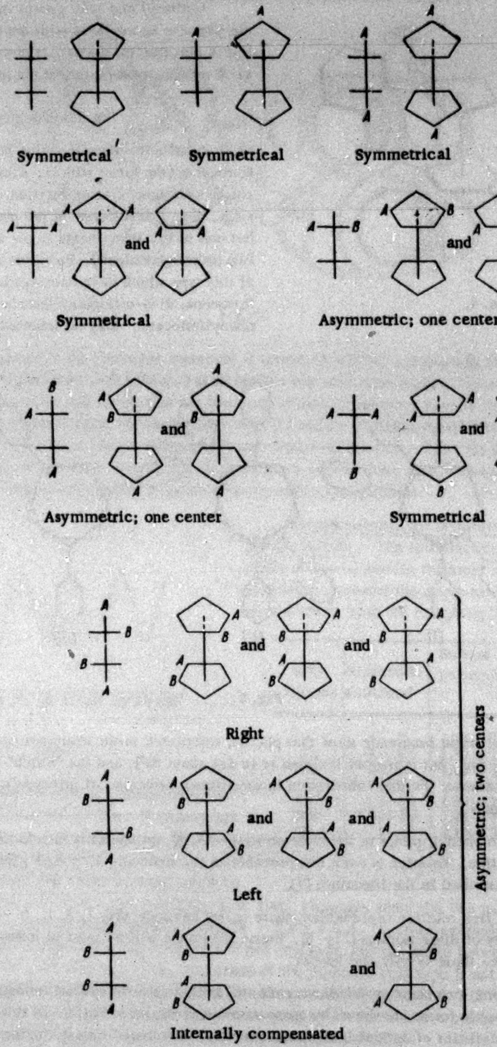
Fig. 5.

Our calculations of steric hindrance show that phenyl, substituted in the ortho position, cannot be coplanar with the five-membered ring, but is steeply inclined to it (at about 60°), and the "catch" of the other five-membered ring prevents its rotation. Further substitution in substituted ferrocenes of this type may lead to the formation of geometrical isomers.

Introduction of two phenyl groups in adjacent positions (1, 2), on one or both five-membered rings, obviously prevents internal rotation. Rotation is even less probable in the molecule 1, 2, 4, 1', 2', 4' -hexaphenylferrocene, which has been described in the literature [7].

If, for any reason, free rotation is prevented, there is, for example with 1, 3, 1', 3' -tetraphenylferrocene, the theoretical possibility of three isomers (Fig. 5). Steric hindrance will be least in isomer III; consequently, it is found that in practice there is only one isomer.

Substituted ferrocenes can show molecular asymmetry so that cases of optical isomerism may occur amongst them. The different possible forms are shown by comparison with ethane in Fig. 6. In this treatment, from the point of view of the possibilities of optical isomerism, each five-membered ring in the ferrocene molecule is equivalent to a tetrahedral carbon atom. Up until now, only one ferrocene derivative has been obtained showing molecular asymmetry, namely 1,1'-dimethyl-2,2' -diphenylferrocene [8] (Fig. 7).


Symmetrical
Symmetrical
Symmetrical
and
Symmetrical
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Asymmetric; one center
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Asymmetric; one center
and
Symmetrical
and
and
Right
and
and
Left
and
Internally compensated
Asymmetric; two centers

Fig. 6.

The stereochemistry of disubstituted ferrocenes has been considered by Riemschneider [9] who succeded in resolving 1,1' -di-(methylethoxy)- methylferrocene into its meso and racemic forms; but here, the optical activity is due to the asymmetric carbon atom of the substituent and is not linked with the specific stereochemistry of the ferrocene nucleus. Hence, Riemschneider's compound belongs to the classical case of the optical isomerism of the tetrahedral carbon atom.

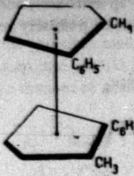


Fig. 7.

Strong chemical evidence for the relative rotation of the five-membered rings in the molecules of substituted ferrocenes is proved by the fact that the corresponding isomers have not been obtained, either by direct synthesis of the polysubstituted ferrocenes from substituted cyclopentadienes, or by repeated substitution of ferrocene itself. Undoubtedly, in the second case the absence of rotation isomers may equally well be explained by the powerful orientating influence of the first substitutent.

One of the few chemical indications of internal rotation is taken from Pauson's survey [8]. Acetylation of acetylferrocene (I) (Fig. 8) only succeeds in introducing one further acetyl group to give diacetylferrocene (II), since the presence of the first acetyl group strongly deactivates the ferrocene nucleus for further substitution.

Partial reduction of diacetylferrocene (II) gives ethylacetylferrocene (III). On the other hand, reduction of acetylferrocene (I) gives ethylferrocene (IV), the single acetylation of which could theoretically give five isomers of ethylacetylferrocene (V - IX) (Fig. 9).

(V), (VI) and (VII) are rotation isomers; so that, on rotation, these three formulae give one chemical individual, and the total number of isomers will be three instead of five. In practice, this synthesis does give three isomers, showing that internal rotation does occur in the ethylacetylferrocene molecule. The isomer with substituents in different rings, formulae (V - VII), is identical with the ethylacetylferrocene (III) obtained by different means. The infrared spectra of isomers (VIII) and (IX) show that these are 1, 2- and 1, 3-disubstituted ferrocenes, since the spectra contain bands characteristic of all ferrocene derivatives with one unsubstituted ring.

Thus, the number of possible isomers is greatly reduced by internal rotation, as the result of which many position isomers (with substituents in different rings) turn out to be ephemeral rotation isomers. In the absence of the necessary steric hindrance, internal rotation destroys the orientating influence of a substituent in one ring on substitution in the other. But it is suggested that this view, though generally accepted at present, has been formulated too hastily or inaccurately. Indeed, it is quite clear that mutual influence does exist between the rings of the ferrocene molecule, since disubstituted ferrocenes (products of disubstitution in the same ferrocene) are found, preferentially, to be derivatives with the substitutents in different rings. The mutual influence can indeed show itself by preferential orientation, which is only masked by internal rotation.

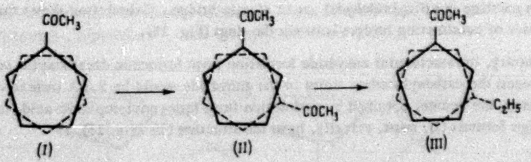


Fig.8.

In the case of disubstituted ferrocenes (substituents in different rings) three rotation isomers are possible ("center of symmetry" carbon atoms of the different five-membered rings of the ferrocene nucleus are conveniently numbered with a single figure, using a supplementary stroke to denote the carbon atoms of one of the rings) (Fig.10).

Undoubtedly, the introduction of a substituent must alter the potential curve shown above, and three variants are possible in the case considered (Fig. 11). The 1,3' isomer is the least probable, particularly because of the spatial interference between the substituents.

However, this is not so if the substituents interact with each other (as in hydrogen bond formation or with substituents of the type NH_2 and Cl). The steric difficulties are equivalent for the 1,1' - and 2,2' - isomers, so that it is essential to find out which of these two configurations is present in the crystal. If both configurations are found (without any systematic connection with the character of the substitutent), then, clearly, the orientating effect must be so small that it is easily overcome by the tendency toward dense packing. But if, systematically, only one form is observed, this would clearly reveal an orientating influence for substitution between the five-membered rings. This conclusion is not necessarily in conflict with the fact that, up until now, only one isomer has been obtained instead of three. It is possible that the two others are not present, precisely because of the orientating influence between the rings.

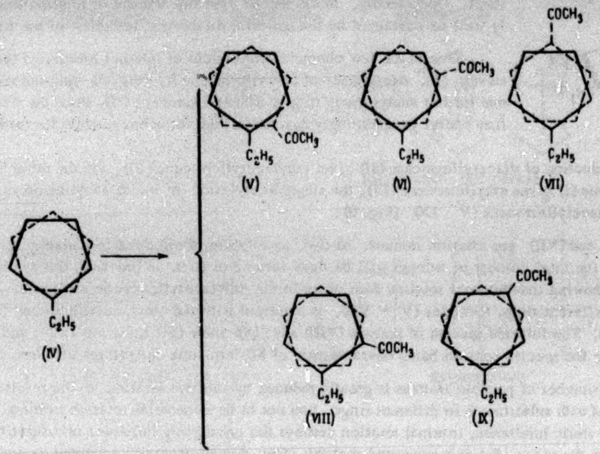


Fig. 9.

The stereochemistry of bridged ferrocene derivatives. Internal rotation in the ferrocene molecule is prevented, not only by the introduction of large "awkward" groups, but also by the creation of direct linkages between the five-membered rings (Fig. 12). Such a linkage can be, for example, an intramolecular hydrogen bond (of the type existing in salicylaldehyde) or an atomic bridge. Calculation shows that there are a number of possible methods of constructing bridges between the rings (Fig. 13).

On the contrary, intramolecular anhydride formation from ferrocene dicarboxylic acid cannot occur, as the distance between the carboxyl carbon atoms in the anhydride would be 2.3 A instead of the required 3.4 A. For the same reason, the ketone, obtained by cyclization from ferrocenylpropionic acid, to which Pauson [8] ascribed the bridge formula (I), must, actually, have the structure (II) (Fig. 15).

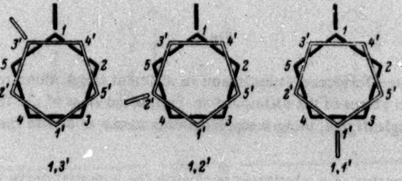
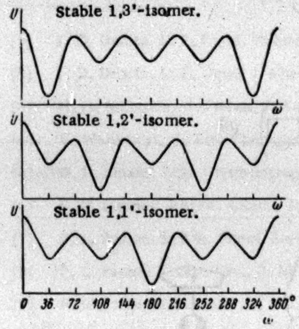


Fig. 10.

Particularly interesting from the stereochemical point of view are the bridged bisferrocenylenemethane (I) and bisferrocenylenephenylmethane (II) synthesized by I. I. Kritskaya [10] (Fig. 16). For such molecules four possible models can be constructed, using bonds of normal length (Fig. 17). Calculation shows that models (I) and (II) can be rejected, as they are subject to very great strain, i. e. they are characterized by considerable distortion of the valence angles or anomalous reduction of the distance between unlinked atoms. On the other hand, models (III) and (IV) are unstrained. The intramolecular distances Fe–Fe differ considerably, so that x-ray structural analysis can distinguish between the two. Model (IV), with four phenyl substituents, is the only known example of a molecule with 222 symmetry (three mutually perpendicular axes of the second order). Both the probable models are assymmetrical, and it would be interesting to attempt to resolve bisferrocenylenemethanes into optical isomers. It would also be interesting to obtain substituted derivatives, which would have a large number of possible isomers.


Stable 1,3'-isomer.

Stable 1,2'-isomer.

Stable 1,1'-isomer.

Fig.11.

Direction of x-ray structural investigation of ferrocene derivatives. The peculiarity of the stereochemistry of ferrocene makes necessary the establishment of the molecular configuration of any of its derivatives. Up until now, no structural investigations of ferrocene derivatives have been published. We have undertaken the x-ray structural investigation of all the well-crystallized ferrocene derivatives, synthesized in the laboratories of the Institute of Heteroorganic Compounds of the Acad. Sci. USSR and the chemical faculty of the Moscow State University [10, 11].

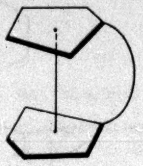
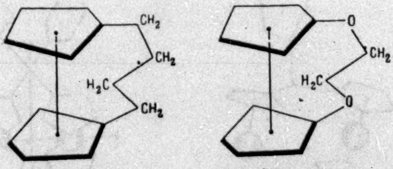


Fig. 12.

The lattices of nearly all these disubstituted bridge derivatives, and of ferrocene itself, have practically the same lesser parameter equal to 6.0± 0.3 A. So the projections along the short axis must be similar for all these structures. This greatly facilitates the x-ray structural analysis. The fundamental object of these investigations is to establish the molecular configurations and steric hindrance effects, which, in a number of cases (bridged compounds), practically amounts to an objective proof of structural formulae assigned to them. During the years 1955-1956 we principally investigated the diketoferrocenes: the full structure of dibenzoylferrocene was established and preliminary results were obtained for the structures of diacetyl-, dipropionyl-, and dibutyryl-ferrocene [12].



No. of CH_2 groups:
n ≥ 4.

No. of CH_2 groups:
n ≥ 2.

Fig. 13.

In conclusion, the author would like to thank A. I. Kitaigorodsky for his interest in the work.

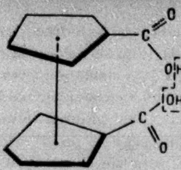
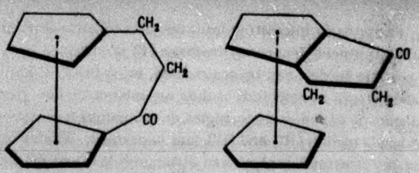
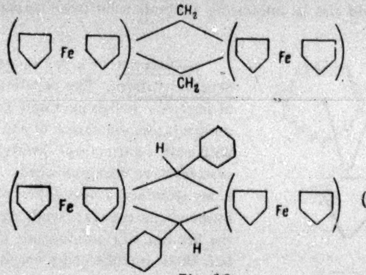


Fig. 14.


CH₂
CH₂
CO
CO
CH₂
CH₂

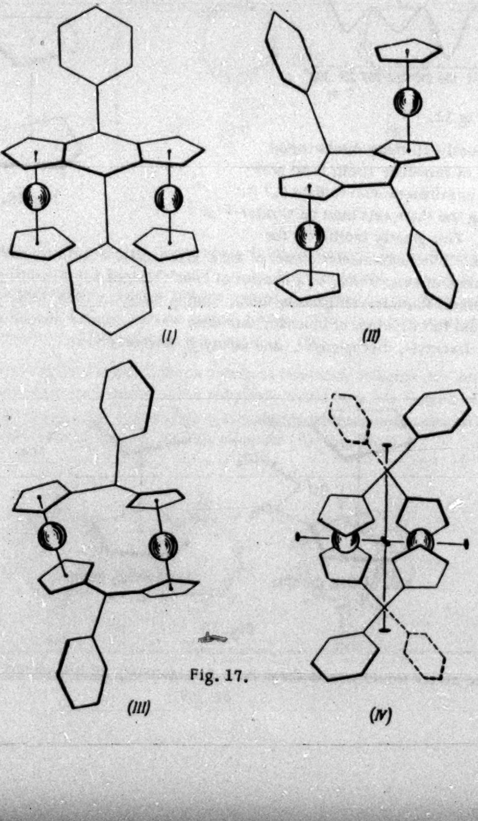
(I) Fig. 15. (II)


CH₂
Fe
Fe
CH₂
H
Fe
Fe
H

(I)

(II)

Fig. 16.



(I) (II)

Fig. 17.

(III) (IV)

SUMMARY

1. Steric effects between the cyclopentadiene rings in the ferrocene molecule are discussed, and some obstacles to relative rotation are established.

2. The stereochemistry of ferrocene derivatives and the effect of the nature of the substituent on the potential curve of the relative rotation of the cyclopentadiene rings are discussed. The possibilities of geometrical and optical isomerism are analyzed, with consideration of the nature, number and positions of the substituents.

3. The geometrical conditions are established for "bridge formation" between the cyclopentadiene rings of the ferrocene molecule, and possible configurations for bisferrocenylene derivatives are analyzed.

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* Original Russian pagination. See C. B. translation.

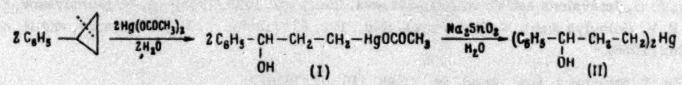
REACTION OF CYCLOPROPANE HYDROCARBONS WITH MERCURIC SALTS. VII. THERMAL DECOMPOSITION OF SYMMETRIZATION PRODUCTS OF γ-MERCURATED ALCOHOLS

R.Ya. Levina, V.N. Kostin, and V.A. Tartakovsky

From the work of G. A. Razuvaev and M. M. Koton [1-3] it is known that the thermal decomposition of fully substituted symmetrical organomercury compounds proceeds by a radical mechanism with the liberation of metallic mercury and the formation of free radicals. Thus, for example, the final products of the thermal decomposition of diphenylmercury are mercury and diphenyl. When the reaction is carried out under hydrogen pressure or in a solvent capable of serving as a hydrogen donor (alcohol [2], hydrazobenzene [3]), the decomposition of diphenylmercury proceeds with the formation of mercury and benzene.

$$(C_6H_5)_2Hg \rightleftarrows Hg + 2C_6H_5^{\cdot}$$
$$2C_6H_5^{\cdot} + RCHOH{-}R \longrightarrow 2C_6H_6 + RCOR$$

The symmetrization of γ-mercurated alcohols (I), obtained by the reaction of cyclopropane hydrocarbons with mercury acetate (in aqueous solution) leads to the formation of fully substituted symmetrical organomercury compounds (II), which contain hydroxyl groups in the molecule; for example [4]:



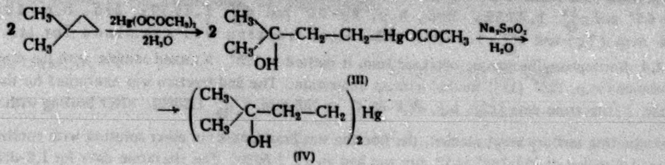
One might assume that in the thermal decomposition of such a fully substituted organomercury compound (II) the secondary alcohol groups in it serve as a source of hydrogen necessary for the reduction of the radicals formed, i.e. that a reduction reaction will take place even in the absence of solvents that split off hydrogen.

The investigation carried out in the present work confirmed the correctness of this assumption: the products of the thermal decomposition of di-(3-hydroxy-3-phenylpropyl) mercury (II) were shown to be ethylphenyl ketone and ethylphenyl carbinol.

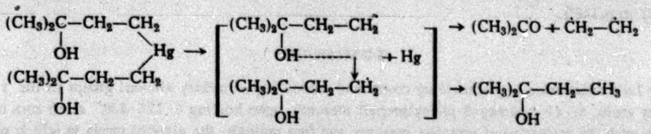
$$\underset{(II)}{(C_6H_5CHOHCH_2CH_2)_2Hg} \longrightarrow [Hg + 2C_6H_5CHOHCH_2CH_2^{\cdot}] \longrightarrow$$
$$\longrightarrow Hg + C_6H_5COCH_2CH_3 + C_6H_5CHOHCH_2CH_3$$

Ethylphenyl ketone was identified by the crystalline 2,4-dinitrophenylhydrazone; ethylphenyl carbinol by the crystalline 3,5-dinitrobenzoate.

It was of interest to clarify the behavior in this reaction of the fully substituted organomercury compounds having in the molecule tertiary alcohol groups in the γ-position to the mercury atom. Such compounds are easily prepared from hemidialkylcyclopropanes; for example [5]:



In the investigation of the thermal decomposition of di-(3-hydroxy-3-methylbutyl) mercury (IV) it was established that the products of this reaction were tertiary amyl alcohol and acetone; the reaction thus proceeded according to the scheme



An unsaturated hydrocarbon also was present in the reaction product, which boiled in the temperature range 55-101°; judging by the boiling temperature, the sole hydrocarbon component might be a trimer of the ethylene that was split out – hexene-1 (with a possible trace of isomeric hexenes). A dibromide obtained from the corresponding fraction had constants close to those of 1,2-dibromohexane. (Formation of gaseous unsaturated hydrocarbons – ethylene or butylenes – in the reaction was not observed).

Thus, in the thermal decomposition of fully substituted organomercury compounds containing secondary or tertiary alcohol groups in the γ-position to the mercury atom, one of the decomposition products is the corresponding alcohol, from the structure of which can be judged the structure of the starting organomercury compound; a second product of the reaction is a ketone, the formation of which occurs in the first instance without change in the carbon skeleton of the radical, and in the second instance with splitting of a C–C bond in it.

EXPERIMENTAL

Thermal decomposition of di-(3-hydroxy-3-phenylpropyl) mercury (II, 30 g; m.p. 77-78° [4]) took place when this compound was heated in vacuo up to 120-130° (15 mm); during this process the organic reaction products and part of the mercury distilled off (for the absorption of the mercury vapors the receiver was connected with a U-tube filled with activated carbon). The condensate, which was a mixture of ethylphenyl carbinol and ethylphenyl ketone, was filtered off from the mercury and again distilled:

b.p. 210-212° at 754 mm, n_D^{20} 1.5289; yield 14.5 g (85%). Literature data: ethylphenyl carbinol [6] – b.p. 212° at 758 mm; n_D^{20} 1.5257, ethylphenyl ketone [7, 8] – p.p. 215° at 750 mm; n_D^{20} 1.5270.

Since it was not possible to separate these two reaction products with such close boiling points by distillation, each of them was identified by preparing a crystalline derivative: from one portion of the fraction boiling at 210-212° was prepared the 3,5-dinitrobenzoate of ethylphenyl carbinol with m.p. 67° (from alcohol), and from a second portion was prepared the 2,4-dinitrophenylhydrazone of ethylphenyl ketone with m.p. 192° (from alcohol). A mixed sample of these derivatives with 3,5-dinitrobenzoate of known ethylphenyl carbinol (m.p. 67°; literature data : [9]: m.p. 67°) and 2,4-dinitrophenylhydrazone of known ethylphenyl ketone* (m.p. 192° literature data [10]: m.p. 189°), respectively, melted without depression.

Thermal decomposition of di-(3-hydroxy-3-methylbutyl) mercury (IV, 45 g. m.p. 81° [5]) took place when this organomercury compound was heated up to 100-110°. the reaction products** that distilled off during

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[*] A mixed sample of the preparation obtained (m.p. 192°) with the starting 2,4-dinitrophenylhydrazine (m.p. 196°) melted with considerable depression (at 162°).

[**] Evolution of gaseous unsaturated hydrocarbons (ethylene or butylenes) did not occur – in a control flask with bromine after the usual treatment of its contents dibromides were not found.

this process were redistilled (total yield 15 g, 71 %). The following fractions were collected: 1st, b.p. 55-65° and n_D^{20} 1.3718; 2nd, b.p. 65-90° and n_D^{20} 1.3977; 3rd, b.p. 100-101° at 755 mm (7g) and n_D^{20} 1.4095. The first fraction was examined for its acetone content; the 2,4-dinitrophenylhydrazone obtained from it melted at 125° a mixed sample with the dinitrophenylhydrazone of acetone (m.p. 126° [11]) melted without depression. The 2nd fraction was examined for the presence of hexene-1 (literature data [12]: b.p. 62.8-63.4° at 758 mm, n_D^{20} 1.3880). after boiling with sodium to remove contaminating tertiary amyl alcohol, the fraction was brominated (in ether solution with cooling); the dibromide obtained distilled at 102-104° at 27 mm and had an n_D^{20} 1.5020. The literature data for 1,2-dibromohexane [13] are: b.p. 61-62° at 4 mm, n_D^{20} 1.5010. The 3rd fraction contained basically tertiary amyl alcohol (literature data [14]: b.p. 101.6° at 755 mm, n_D^{20} 1.4052). the 3,5-dinitrobenzoate obtained from it melted at 117° and gave no depression in melting point when mixed with the 3,5-dinitrobenzoate of tertiary amyl alcohol (m.p.116°; literature [15]: m.p.116°).

SUMMARY

1. The fully substituted organomercury compound containing secondary alcohol groups in the γ-position to the mercury atom, di-(3-hydroxy-3-phenylpropyl) mercury, upon heating to 120-130° at 15 mm undergoes decomposition with the formation of metallic mercury and free radicals, the alcohol group in which serves as a source of hydrogen for their reduction. The reaction products are the corresponding alcohol (ethylphenyl carbinol) and ketone (ethylphenyl ketone).

2. The fully substituted organomercury compound containing tertiary alcohol groups in the γ-position to the mercury atom, di-(3-hydroxy-3-methylbutyl) mercury, upon heating to 100-110° decomposes with the separation of metallic mercury and the formation of free radicals; part of them undergo further decomposition at the site of the tertiary alcohol group with the formation of a ketone (acetone), ethylene (which further trimerizes), and hydrogen, which adds to another part of the radicals to produce a tertiary alcohol (dimethylethylcarbinol).

3. The structure of the fully substituted organomercury compounds containing secondary or tertiary alcohol groups can be established from the structure of their thermal decomposition productus – alcohols and ketones.

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EQUILIBRIA OF REACTIONS BETWEEN HYDROCARBONS

X. HEAT CAPACITIES OF NAPHTHALENE, TETRALIN, AND DECALIN

A.A. Vvedensky and D.M. Maiorov

To carry out thermodynamic calculations on the hydrogenation of naphthalene to tetralin and decalin or any other reactions in which these hydrocarbons may participate, it is necessary to know the relationship of the heat capacities of these hydrocarbons to temperature. The heat capacity of naphthalene vapors at 451 and 522° K experimentally determined by McClellan and Barrow agreed well with the calculated values obtained from spectroscopic data [1]. Later McClellan and Pimental, using more exact spectroscopic data, calculated the heat capacity of naphthalene for the temperature interval 300 to 1500° K [2].

So far as we know, data on the heat capacity of tetralin and decalin in relation to temperature are not given in the literature.

In the work here presented we set forth calculations on the heat capacities of naphthalene, tetralin, and decalin from spectroscopic data, using the formula of Stull and Mayfield [3].

$$C_p^0 = 4R + \frac{a \cdot R}{2} + \sum g_i E_{\nu_i} + \Phi \sum g_i E_{\delta_i} \qquad (1)$$

In equation (1)

$$\Phi = \frac{3n - 6 - a - \Sigma g_i}{\Sigma g_i},$$

where C_p^0 is the heat capacity in cals / degree mole at $p = 0$, Σg_i is the number of bonds in the molecule; n is the total number of atoms in the molecule; $E\nu_i$, $E\delta_i$ are the Einstein functions for a given bond with characteristic vibration frequencies ν_i and δ_i; R is the gas constant; a is the number of bonds that permit free rotation of individual groups of atoms in the molecule.

For naphthalene, tetralin, and decalin we assumed $a = 0$.

In Table 1 the values are given for the heat capacity of naphthalene calculated by us from this formula in comparison with the data of McClellan and Pimental.

From the data of Table 1 it follows that the calculated values are in fully satisfactory agreement.

The heat capacities for tetralin and decalin were also calculated by formula (1). The results obtained are given in Table 2.

The relationship of the heat capacities of naphthalene, tetralin, and decalin to temperature in the interval 300-1000° K, using the method of least squares, was expressed in the following series of equations.

For naphthalene: $C_p^0 = -7.66 + 0.14711T - 0.00006208\,T^2$ (2)

For tetralin: $C_p^0 = -8.90 + 0.1725\,T - 0.0000707\,T^2$ (3)

For decalin: $C_p^0 = -10.48 + 0.209\,T - 0.0000823\,T^2$ (4)

The heat capacities calculated from these equations agree satisfactorily with the heat capacities calculated according to equation (1) (deviation did not exceed 0.4 cals / deg mole).

TABLE 1

Heat Capacity of Naphthalene at p = 0

Temperature (in°K)	C_p° (in cals / deg mole)		Deviation
	according to McClellan and Pimental	according to equation (1)	
300	32.28	30.59	—1.69
400	43.20	41.36	—1.84
500	52.44	50.77	—1.67
600	59.94	58.47	—1.47
700	66.01	64.75	—1.26
800	71.00	69.91	—1.09
900	75.13	74.18	—0.95
1000	78.59	77.74	—0.85
1100	81.52	80.76	—0.76
1200	84.00	83.88	—0.12
1300	86.11	85.49	—0.62
1400	87.93	87.37	—0.56
1500	89.49	88.87	—0.62

TABLE 2

Heat Capacity of Tetralin and Decalin at p = 0

Temperature (in°K)	C_p° (in cals./deg mole)	
	tetralin	decalin
300	36.22	44.60
400	48.89	60.03
500	60.12	73.57
600	69.41	85.65
700	77.08	95.43
800	83.45	103.65
900	88.81	110.64
1000	93.30	116.56
1100	97.17	121.72
1200	101.32	127.44
1300	103.30	130.01
1400	105.77	133.33
1500	107.89	136.23

The equations obtained were used to calculate the equilibrium constant for the hydrogenation of naphthalene to tetralin, and decalin which will be the subject of a subsequent communication.

SUMMARY

The heat capacities of naphthalene, tetralin, and decalin in relation to temperature have been calculated.

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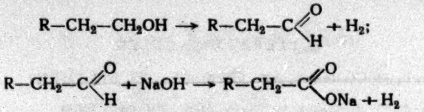
PREPARATION OF CARBOXYLIC ACIDS FROM PRIMARY ALCOHOLS AT REDUCED TEMPERATURES

V.I. Lyubomilov, A.I. Kutsenko, and R.A. Abramova

The condensation reaction of alcohols in the presence of their alcoholates, discovered in their time by Markovnikov and Zubov [1] and studied in detail by Guerbet [2] in the case of the primary alcohols, is always accompanied by a secondary reaction – the formation of salts of the corresponding carboxylic acids. The formation of the salts of the carboxylic acids is connected with the basic condensation reaction of the alcohol: the water given off in the reaction process decomposes the alcoholate with the formation of alcohol and free alkali, which further yields the salt of the carboxylic acid. If the condensation of primary alcohols is carried out in the presence of dehydrogenating catalysts, it proceeds at 120-150° instead of 250-300°, while the formation of the salts of the acids in this case takes place the same as at the high temperatures [3]. In our opinion, this is explained by the fact that the alkali acts in this process on the primary reaction product formed – the aldehyde. In the presence of the same dehydrogenation catalyst, the aldehyde forms with the alkali a salt of the carboxylic acid.



$$R{-}CH_2{-}CH_2OH \rightarrow R{-}CH_2{-}C{\overset{O}{\underset{H}{\lessgtr}}} + H_2;$$

$$R{-}CH_2{-}C{\overset{O}{\underset{H}{\lessgtr}}} + NaOH \rightarrow R{-}CH_2{-}C{\overset{O}{\underset{ONa}{\lessgtr}}} + H_2$$

Starting the condensation reaction of the primary alcohols in the presence of the alcoholate and the catalyst and adding water or free alkali in the course of the reaction, we were able to direct the reaction toward the formation of the acids. This reaction proceeds at temperatures of only 120-150° in distinction from the usual method of preparing the acids, according to Dumas and Stas [4], which requires the use of temperatures of the order of 250-300°. Thus, we obtained in satifactory yields butyric acid from butyl alcohol, isovaleric acid from isoamyl alcohol, and also in preliminary experiments succinic acid from butanediol-1,4 and adipic acid from hexanediol-1,6. The yield of monobasic acids was 56.71%. If we take into account that along with this there is formed a certain amount of alcohols with double the number of carbon atoms and also higher molecular weight alcohols that are of considerable value, then the yield of useful products was of the order of 80-85%

EXPERIMENTAL

A solution of alcoholate in the corresponding alcohol was prepared in an iron pot (1) (see figure) either by dissolving metallic sodium in the alcohol or by distilling off water from a solution of sodium hydroxide in alcohol, using a rectifying column (3). In the latter case the rectifying column had an efficiency of 5-6 theoretical plates. In the upper part it was provided with a water trap (5), the construction of which is shown in the figure. When stopcock A is open and stopcock B is closed, the vapors of the water and alcohol rise through the column, condense in the dephlegmator (4), and the distillate drains into the water trap. The water collects in the lower part of the trap, and the alcohol layer with a small amount of dissolved water is returned to the upper part of the column as reflux. For better separation of the water it is useful to introduce into the reaction mixture a small amount of toluene. The rectifying column was replaced with a reflux condenser (7), to which was connected a gasometer (8), by closing stopcock A and opening stopcock B.

A weighed amount of catalyst was added to the solution of alcoholate that had been prepared, and while

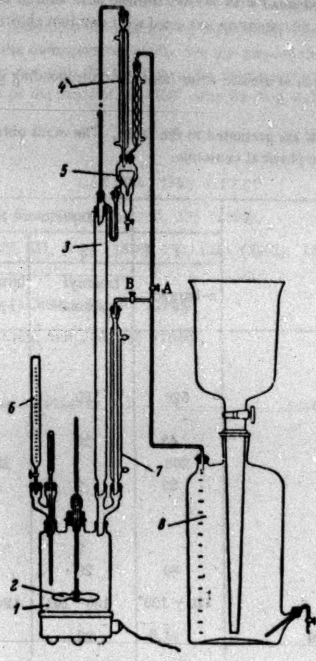


Diagram of apparatus for the preparation of carboxylic acids. Explanation in text.

mixing with a stirrer (2), the reaction mixture was heated with the reflux condenser in operation. When the evolution of hydrogen began, we started to add to the reaction mixture from a burette (6) an amount of water equivalent to the hydrogen given off. The reaction was continued until the evolution of hydrogen ceased. Solid sodium hydroxide was further added to the pot in separate portions, whereupon the process was continued in similar fashion. Since the reaction mass gradually becomes so viscous that it is difficult to stir and side reactions begin to occur which lower the yield of acid, it is expedient to work in a solvent medium.

The most suitable solvent appeared to be 2-ethylhexanol-1, which was practically unchanged under the conditions described. In the case of the conversion of butyl alcohol to butyric acid, it was possible to simplify the method of operation considerably. n-Butyl alcohol, 2-ethylhexanol-1, sodium hydroxide, and catalyst were loaded into the reaction vessel. Water was distilled off. When the amount of it reached 2/3 of that theoretically necessary for the formation of the alcoholate, vigorous evolution of hydrogen started. The column was replaced by the reflux condenser and the reaction was carried on as described above.

As catalysts a reactive basic copper carbonate, which was dried at 120-130° for 2-3 hours, and a commercial catalyst "nickel on chromic oxide," usually employed for hydrogenation, were used.

In all case, for further working up of the products the reaction mass was dissolved in water, the alcohols were distilled off with steam and rectified for separation of the unreacted alcohol, the alcohols with double the of carbon atoms (for example, in the case of n-butanol – 2-ethylhexanol), and higher alcohols. The aqueous solution of the salts remaining from the steam distillation was filtered off from the catalyst, evaporated to a salt concentration of 30-40%, and decomposed with 90-95% sulfuric acid used in an amount equivalent to the starting alkali. The layer of organic acids that separted was dried with calcium chloride and distilled with a herringbone dephlegmator 20 cm in height.

Experiments on the preparation of dibasic acids from the corresponding glycols showed the possibility of such a reaction in principle.

The results of all experiments are presented in the Table. The acids obtained were characterized by their acid number and by the appropriate physical constants.

Conditions and results of experiments	Experiment Numbers			
	1	2	3	4
	n-butanol	isoamyl alcohol	butanediol--1,4	Hexanediol--1,6
Charge (in g):				
alcohol	520	160	45	40
metallic sodium	–	–	5.75	5.75
sodium hydroxide	43	20	–	
solvent	200	–	250	250
catalyst*	23	2	10	10
Added (in g):				
water	–	9	–	3
sodium hydroxide	80	20	30	20
Temperature	120 – 125°	130 – 141°	126 – 153°	138 – 168°
Duration of reaction (in hours)	21.5	20	15	20
Hydrogen evolved (in l)	137.9	44	25	21
Obtained (in g):				
starting alcohol	216.5	68	–	–
alcohol with double the number of carbon atoms	51.8	4.5	–	–
higher alcohols	10.0	1.0	–	–
Name of acid	Butyric	Isovaleric	Succinic	Adipic
Yield of acid				
in g	214	75.5	8.1	10.2
in % of theoretical	59.5	71	–	–
Properties of acid obtained:				
boiling point	161 – 163°	171 – 173°	–	–
melting point	–	–	180 – 181°	149 – 150°
specific gravity	d_4^{20} 0.9584	d_{20}^{20} 0.930	–	–
acid number	638	541	917.5	770.8

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* In experiments 1, 3 and 4 "nickel on chromic oxide" was used as catalyst, in experiment 2 basic copper carbonate.

SUMMARY

The possibility has been demonstrated of directing the Markovikov-Guerbet reaction in the case of primary alcohols toward the formation of the corresponding acids. For this purpose the reaction is carried out in the presence of dehydrogenating catalysts and with the addition to the reaction mixture of water or caustic alkali. The reaction proceeds at temperatures of the order of 120-150° with 56-71% yields of acids and negligible formation of higher alcohols.

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CHLORINATION AND BROMINATION OF PHENYLTRICHLOROSILANE AND THE RAMAN SPECTRA OF HALOGEN-SUBSTITUTED PHENYLTRICHLOROSILANES

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A.D. Matveeva, and B.A. Sokolov

According to the well-known rule for substitution in the benzene ring it would be expected that upon halogenation of phenyltrichlorosilane the substitution by halogen would be predominantly in the meta-position; orientation to the para- and ortho-positions, of course, is not absolutely excluded; the degree to which it occurs depends upon the reaction conditions. It has been shown [1] that under the conditions of photochemical chlorination of phenyltrichlorosilane at 200° formation of all three isomers takes place but the yield of the meta-isomer somewhat predominates.* Thus, under the conditions cited the SiCl$_3$-group actually appears to be meta-orienting, although weakly so.

However, in contradiction to these data and the general rule for substitution in the benzene ring, A. Ya. Yakubovich and G. V. Motsarev [2-5] found that chlorination and bromination of phenyltrichlorosilane in the presence of metallic iron, FeCl$_3$, SbCl$_3$, AlCl$_3$, or I$_2$ at 60-120° leads only to the formation of para-chloro (bromo) phenyltrichlorosilanes.**

It must be noted that Yakubovich and Motsarev chlorinated and brominated comparatively small amounts of phenyltrichlorosilane (7-15 g). To separate the reaction products, which had very close boiling points, they used only ordinary vacuum distillation. Obviously, the difference in the constants for p-chlorophenyltrichlorosilane obtained by us and by them, which already has been note [1], does not therefore appear to be accidental. Moreover, for evidence of the structure of the products obtained these authors employed splitting with bromine water of very small amounts of material (1.3-2.2 g). All that has been said impelled us to return to the investigation of the chorination and bromination of phenyltrichlorosilane.

We carried out the chlorination and bromination of phenyltrichlorosilane in rather considerable amounts (120-140 g). For the separation of the halogenation products we employed a column of 35-40 theoretical plates. The results of fractional distillation of the chlorination and bromination products of C$_6$H$_5$SiCl$_3$ are presented in Fig. 1 and 2 respectively. The distillation curves show that the chlorination and bromination of phenyltrichlorosilane is not so simple a process as Yakubovich and Motsarev maintained. Thus, chlorination of C$_6$H$_5$SiCl$_3$ in the presence of metallic iron at 70°, like photochemical chlorination at 200°, leads to the formation of o-chlorophenyltrichlorosilane, a dichloride (the structure of which we did not establish), and low-boiling products, which from their boiling points might be a mixture of p- and m-chlorophenyltrichlorosilanes.

We carried out an optical investigation of the composition of the chlorination products (Fig. 1) in the fractions with b.p. 230.5° at 730.5 mm and 241.5° at 730.5 mm and the bromination products (Fig. 2) in the fraction with b.p. 249-260.5° at 752.5 mm. For this purpose we first prepared pure chloro- and bromophenyltrichlorosilanes, the constants of which are given in Table 1. We obtained their spectra in a three-prism ISP-51 spectrograph with a medium cell from the 4358 A exciting line of a mercury lamp. The spectra are given in Table 2.

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* We make use of this opportunity to more precisely define the composition of the mixture of chlorophenyltrichlorosilanes formed by this reaction, which contains ortho-, meta- and para-isomers in the amount of 25, 60, and 15% respectively.

** The authors explain such an "anomalous" orientation in one of their publications [2] by the fact that the catalysts mentioned above form adducts with the SiCl$_3$ group, leading to a change in the charge on the Si and consequently to a change in the orientation.

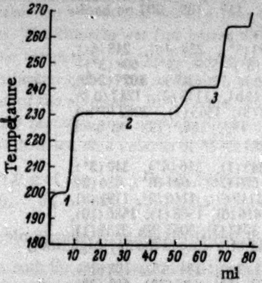

Fig. 1. Distillation curve of chlorination products of $C_6H_5SiCl_3$.
1) $C_6H_5SiCl_3$, 2) mixture of m- and p-$ClC_6H_4SiCl_3$, 3) o-$ClC_6H_4SiCl_3$, 4) $Cl_2C_6H_3SiCl_3$.

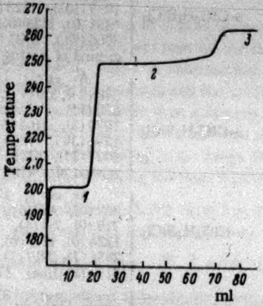

Fig. 2. Distillation curve of bromination products of $C_6H_5SiCl_3$.
1) $C_6H_5SiCl_3$, 2) mixture of m- and p-$BrC_6H_4SiCl_3$, 3) o-$BrC_6H_4SiCl_3$.

TABLE 1

Physical Properties of Chloro- and Bromophenyl- Trichlorosilanes

Formula of compound	Boiling point; pressure (mm)	d_4^{20}	n_D^{20}	MR_D	
				found	calculated
o-$ClC_6H_4SiCl_3$*	240.5° (742.5)	1.4629	1.5510	53.64	53.83
m-$ClC_6H_6SiCl_3$*	230.5 (738)	1.4384	1.5421	53.83	53.83
p-$ClC_6H_4SiCl_3$*	232.5 (745.5)	1.4316	1.5418	54.00	53.83
o-$BrC_6H_4SiCl_3$	261.0—261.5 (768.5)	1.6956	1.5710	56.27	56.67
p-$BrC_6H_4SiCl_3$	251.4—251.7 (746.0)	1.6484	1.5635	57.26	56.67

* See description of preparation of these compounds in [1].

The composition of the above-mentioned fractions from the chlorination and bromination of $C_6H_5SiCl_3$, determined optically, is given in Table 3.

The data in Table 3 and the distillation curves (Fig. 1 and 2) permit the determination of the approximate proportions of ortho-, meta-, and para- isomers formed by the chlorination and bromination of phenyltrichlorosilanes.

The chlorination products (Fig. 1) were: o-chlorophenyltrichlorosilane 24%, m-chlorophenyltrichlorosilane 74%, p-chlorophenyltrichlorosilane 2%. The bromination products (Fig. 2) were: o-bromophenyltrichlorosilane 31%, m-bromophenyltrichlorosilane 31%, p-bromophenyltrichlorosilane 38%.

In connection with what has been stated the question arises of the limits of applicability of splitting with bromine water as evidence of the structure of the chloro- and bromophenyltrichlorosilanes formed. The action of bromine water obviously does not consist only of the rupture of the Si-C bond by bromine; in our opinion it is also necessary to take into consideration other reactions: splitting of the Si-C bond by HCl liberated in the hydrolysis of chloro- and bromophenyltrichlorosilanes and by HBr formed in the cleavage, bromination, etc.

TABLE 2

Raman Spectra of Chloro- and Bromophenyltrichlorosilanes and Phenyltrichlorosilane

o-$\mathrm{ClC_6H_4SiCl_3}$	Δν cm⁻¹: 157 (4b), 188 (7), 207 (5), 268 (2b), 319 (5), 353 (0), 385 (6), 438 (9), 526 (4), 571 (3*)—590 (3*)—601 (3*)—618 (3*) (band), 666 (4s), 685 (0), 710 (0), 750 (0), 869 (0), 895 (0), 1039 (10s), 1123 (5*s), 1137 (2*s), 1164 (4s), 1255 (0), 1279 (1), 1355 (0), 1423 (0), 1457 (0), 1561 (2), 1584 (6), 2965 (2*), 2987 (2*), 3066 (9b), 3121 (3), 3161 (1), (lines 157, 188, 207 on background of a wing of the Rayleigh line).
m-$\mathrm{ClC_6H_4SiCl_3}$	Δν cm⁻¹: 155 (7), 184 (6*), 193 (5*), 234 (4p), 248 (4s), 340 (9s), 356 (9), 427 (4), 518 (6), 578 (3*)—599 (3*)—608 (3*)—620 (1*) (band), 670 (4), 790 (0b), 996 (10s), 1029 (2db), 1079 (3), 1102 (1*), 1117 (1*), 1138 (5b), 1178 (2), 1247 (0b), 1296 (3b), 1396 (3), 1428 (0), 1563 (3), 1585 (7), 3062 (9*b), 3077 (1*), 3119 (3), 3163 (2), (lines 155, 184, 193 on background of a wing of the Rayleigh line.)
n-$\mathrm{ClC_6H_4SiCl_3}$	Δν cm⁻¹: 172 (6*), 190 (3*), 243 (1), 316 (6*), 340 (2*), 369 (0), 452 (6), 578 (4*), 596 (2*), 609 (2*), 621 (0*), 634 (2), 719 (0), 754 (4), 1067 (2), 1091 (10), 1119 (3), 1160 (0), 1191 (3), 1224 (0), 1273 (0), 1307 (2), 1385 (0), 1416 (0), 1568 (1), 1586 (10), 2854 (1), 2917 (1), 2986 (1), 3032 (1), 3047 (3), 3065 (8), 3135 (1), 3158 (2) (lines 172, 190 on background of a wing of the Rayleigh line.)
o-$\mathrm{BrC_6H_4SiCl_3}$	Δν cm⁻¹: 87 (6*), 108 (5*), 141 (3m), 184 (4*), 198 (3*), 263 (2), 285 (3), 373 (10), 521 (4), 579 (3*)—589 (3*)—601 (3*), (band), 623 (1), 654 (4), 1028 (3), 1043 (9s), 1115 (4), 1132 (4), 1168 (5), 1249 (1), 1275 (1), 1296 (1), 1398 (1), 1424 (1), 1557 (4), 1581 (6), 1610 (0), 1634 (0), 2827 (0), 2868 (0), 2907 (0), 2927 (0), 2971 (0), 3050 (4*), 3062 (7*), 3077 (3*), 3087 (0), 3120 (2), 3140 (0), 3157 (1) (lines 87, 108, 141, 184, 198 on background of a wing of the Rayleigh line.)
n-$\mathrm{BrC_6H_4SiCl_3}$	Δν cm⁻¹: 154 (5), 186 (3), 221 (2db), 244 (0), 262 (0), 282 (6), 304 (4*), 319 (2*), 409 (8), 547 (7), 582 (3*)—595 (3*)—607 (3*) (band), 622 (1**), 633 (3**), 714 (0), 739 (6), 1071 (10), 1112 (4*), 1123 (5*), 1191 (5), 1291 (1s), 1306 (1s), 1355 (0), 1393 (0), 1416 (0), 1547 (0), 1577 (10), 1607 (0), 1627 (0), 1663 (0), 2855 (1db), 2959 (2db), 3001 (2*), 3024 (2*), 3046 (6**), 3064 (10**), 3082 (3*), 3102 (3*), 3155 (3) (lines 154, 186, 221 on background of a wing of the Rayleigh line.)
$\mathrm{C_6H_5SiCl_3}$	Δν cm⁻¹: 168 (5), 186 (6), 348 (9), 384 (0), 438 (0), 488 (0), 515 (5), 572 (3*), 587 (3*)—599 (3*) (band), 621 (3), 723 (3) 849 (0), 871 (0), 922 (1), 999 (10), 1031 (5), 1122 (5), 1164 (3), 1191 (2), 1308 (0), 1337 (1), 1382 (1), 1433 (1), 1571 (1db), 1592 (6), 2868 (0), 2916 (0), 2965 (1), 3013 (1), 3035 (0), 3058 (9b), 3138 (1), 3184 (1), (lines 168, 186 on background of a wing of the Rayleigh line.)

Note. Designations of intensities: b – wide line; s – sharp line; db – double line; lines designated by asterisks for intensities are located on a background common to neighboring lines, which are designated by the same number of asterisks.

TABLE 3

Composition of Fractions of the Chlorination and Bromination Products of Phenyltrichlorosilane

No. of fraction	Fractions	Boiling point; pressure (in mm)	Compounds	Yield (in %)
I	Chlorination products (Fig. 1)	230.5° (730.5)	o-$\mathrm{ClC_6H_4SiCl_3}$ m-$\mathrm{ClC_6H_4SiCl_3}$ p-$\mathrm{ClC_6H_4SiCl_3}$	0 97 3*
		241.5 (730.5)	o-$\mathrm{ClC_6H_4SiCl_3}$	100
II	Bromination products (Fig. 2)	249—260.5 (752.5)	o-$\mathrm{BrC_6H_4SiCl_3}$ m-$\mathrm{BrC_6H_4SiCl_3}$ p-$\mathrm{BrC_6H_4SiCl_3}$	10 40** 50

In conclusion we point out that in the light of the data obtained by us the question of the structure of the compounds recently synthesized by K. A. Andrianov and V. A. Odinets [5] from products of the chlorination of phenyltrichlorosilane in the presence of $FeCl_3$, obviously requires a complete review.

EXPERIMENTAL

1. Chlorination of phenyltrichlorosilane. The chlorination of 118 g of material in the presence of 0.59 g of powdered iron was carried out in a flask fitted with a stirrer, reflux condenser, and tube for the introduction of chlorine. The chlorine was first passed through a bottle with conc. H_2SO_4. When the chlorine was passed through, the temperature in the flask rose to 26°; the reaction mixture was then heated and the chlorination process was further carried out at 70 ± 5°, which was achieved both by the use of heat from a furnace and the introduction of the chlorine. In 6.5 hours, when the gain in weight reached 16.3 g, the chlorination was terminated and the reaction products were distilled in vacuo. 132 g of the mixture, boiling in the range 60-135° (6 mm) was distilled on a column of 35-40 theoretical plates (Fig. 1). The following fractions were obtained:

1st, 7.9 g of unreacted $Cl_3SiC_6H_5$, b.p. 198-200° (736.5 mm); 2nd, 55.8 g (43.8%) with b.p. 230.5° (736.5 mm), d_4^{20} 1.4324, n_D^{20} 1.5415, the composition of which was determined with the aid of the Raman spectra (Table 3); calc. 53.83; MR_D 54.00; 3rd, 16.1 g (12.6%) with b.p. 241.5° (730.5 mm), d_4^{20} 1.4616, n_D^{20} 1.5502, which from both the Raman spectral data and the constants given above appeared to be identical with o-chlorophenyltrichlorosilane prepared by us earlier by photochemical chlorination of $Cl_3SiC_6H_5$ at 200° [1] (Table 1); 4th, 15.5 g of a dichloride, the structure of which was not determined: b.p. 264.5-264.8° (729 mm), d_4^{20} 1.5528, n_D^{20} 1.5641.

Found %: C 25.64, 25.55; H 1.09, 1.09; Cl 63.67, 63.22; Si 9.67; 9.85. $C_6H_3Cl_5Si$.
Calculated %: C 25.70; H 1.08; Cl 63.21; Si 10.01.

2. Bromination of phenyltrichlorosilane. In the flask of the apparatus described in experimental 1 were loaded 137 g of $Cl_3SiC_6H_5$ (b.p. 201.5°) and 0.69 g of powdered iron. 105 g of bromine was added dropwise while the contents of the flask were stirred for 6 hours. The reaction temperature was held at 62-65°. 181 g of crude mixture was obtained the distillation of which in vacuo yielded 171.7 g of reaction products boiling in the range 56-101° at 3 mm. By distillation of the latter on a column of 35-40 theoretical plates the following fractions were obtained (Fig. 2):

1st, 25 g of unreacted $Cl_3SiC_6H_5$, b.p. 200.5-201.5° (752.5 mm); 2nd, 5 g of p-dibromobenzene; 3rd, 75.9 g (49.4%) with b.p. 249-253.5° d_4^{20} 1.6473, n_D^{20} 1.5620. The composition of this and the intermediate fraction was determined from the Raman spectra (Table 3); 4th, 25.4 g (16.5%) with b.p. 261.0-261.5° (768.5 mm), d_4^{20} 1.6956, n_D^{20} 1.5710, the constants of which indicated that it was o-bromophenyltrichlorosilane; MR_D 56.28; calc. 56.67.

Found % C 24.74, 24.51; H 1.19, 1.34; Cl + Br 63.75, 64.17; Si 9.99, 9.66. $C_6H_4BrCl_3Si$.
Calculated %: C 24.81; H 1.39; Cl + Br 64.14; Si 9.66.

3. m-Chlorophenyltrichlorosilane was prepared in the amount of 11.5 g from m-chlorobromobenzene under the conditions previously described [1];

b.p. 231-231.5° (750 mm), d_4^{20} 1.4361, n_D^{20} 1.5408, MR_D 53.80; calc. 53.83.

4. p-Bromophenyltrichlorosilane was prepared in two experiments from 236.6 g of p-dibromobenzene, 24.6 g of magnesium and 339 g of $SiCl_4$ in 850 ml of absolute ether under conditions similar to those for the preparation of p-chlorophenyltrichlorosilane [1]. 71.5 g of crude p-bromophenyltrichlorosilane, separated from the mixture of reaction products by vacuum distillation (4 mm), was twice distilled on a column of 35 theroretical plates:

b.p. 251.4-251.7° at 746 mm, d_4^{20} 1.6484, n_D^{20} 1.5635, MR_D 57.26; 57.67.
Found %: C 24.77, 25.02; H 1.25, 1.36; Cl + Br 64.32, 64.30; Si 9.65, 9.41. $C_6H_4BrCl_3Si$.
Calculated %: C 24.81; H 1.39; Cl + Br. 64.14. Si 9.66.

SUMMARY

1. It has been shown that chlorination of phenyltrichlorosilane in the presence of powdered iron at 70° gives a mixture of m-, p-, and o-chlorophenyltrichlorosilanes with a predominance of the first.

2. It has been shown that bromination of phenyltrichlorosilane under the same conditions leads to the formation of all the possible bromophenyltrichlorosilanes in approximately equal amounts.

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REACTION OF DIALKYLCHLOROSILANES WITH ALUMINUM CHLORIDE

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Thermal and catalytic transformations of dialkyl (aryl) chlorosilanes have been little studied. In a patent [1] it is indicated that by heating diphenylchlorosilane or a mixture of it with diphenyldichlorosilane in the presence of $AlCl_3$ (not more than 10% by weight) at 150-200° and a pressure not higher than 60 mm phenyldichlorosilane and traces of phenylchlorosilane are obtained. Recently we have shown [2] that upon distillation of diethylchlorosilane with 9 mole-% of anhydrous $AlCl_3$ disproportionation occurs (a combined hydrogenation-halogenation reaction).

$$2(C_2H_5)_2SiHCl \xrightarrow{AlCl_3} (C_2H_5)_2SiH_2 + (C_2H_5)_2SiCl_2 \qquad (1)$$

The conversion of diethylchlorosilane in this process amounts to 77%, and the respective yields of diethylsilane and diethyldichlorosilane are 44 and 80% as a result of the disproportionation of diethylchlorosilane.

Continuing the investigation of this reaction, which is interesting both theoretically and practically, we discovered that by increasing the amount of $AlCl_3$ taken for the reaction to 20 mole-% the conversion of diethylchlorosilane rose to 94% and this was accompanied by a substantial change in the character of the transformation. The yield of diethylsilane decreased considerably and the reaction products contained besides diethyldichlorosilane a new component, triethylchlorosilane, which apparently appeared as a result of a more deep-seated transformation of diethylchlorosilane

$$3(C_2H_5)_2SiHCl \xrightarrow{AlCl_3} C_2H_5SiH_3 + (C_2H_5)_2SiCl_2 + (C_2H_5)_3SiCl \qquad (2)$$

The formation of triethylchlorosilane cannot be the result of disproportionation of diethyldichlorosilane, inasmuch as the latter did not undergo any change when it was refluxed for 31 hours in the presence of 20 mole-% of $AlCl_3$. Adding equations (1) and (2) it is possible to represent the disproportionation reaction of diethylchlorosilane by equation (3).

$$5(C_2H_5)_2SiHCl \xrightarrow{AlCl_3} C_2H_5SiH_3 + (C_2H_5)_2SiH_2 + 2(C_2H_5)_2SiCl_2 + (C_2H_5)_3SiCl \qquad (3)$$

This equation explains well the fact that when $(C_2H_5)_2SiHCl$ reacts with 20 mole-% of $AlCl_3$, the yield of $(C_2H_5)_2SiCl_2$ exceeds that theoretically possible from equation (2), while on the basis of equation (3) the yield of the latter is 95% and the yield of triethylchlorosilane is 100% based on the diethylchlorosilane reacting. Removal from the reaction zone of the readily volatile ethylsilane (b.p. – 14°) obviously facilitates completion of the conversion.

When an isomer of diethylchlorosilane, methyl-n-propylchlorosilane, was distilled over 8 mole-% of $AlCl_3$ the reaction proceeded according to equation (1) with 72% conversion. The yield of methylpropylsilane, and methylpropyldichlorosilane respectively was 56 and 79% based on the methylpropylchlorosilane reacting.

Another isomer of diethylchlorosilane, methylisopropylchlorosilane, reacted with 10 mole-% of $AlCl_3$ also according to equation (1), 60-65% being converted to methylisopropylsilane and methylisopropyldichlorosilane, the yields of which were 48 and 86-94% respectively based on the methylisopropylchlorosilane reacting.

Thus, employing reaction (1) we were able to prepare and compare the properties of three isomeric silapentanes – 2- and 3-silapentanes (V and IV) and 2-sila-3-methylbutane (VI) – and also their Si-mono- and dichloro derivatives. The properties of the compounds that were investigated, five of which were prepared for the first time, are given in the Table. It should be noted that the newly prepared methylpropylsilane (V) and methylisopropylsilane (VI) are the first representatives of dialkylsilanes of the type $RR'SiH_2$, where $R \neq R'$.* All the dialkylsilanes prepared by us were characterized by extreme volatility.

In 1947 Whitmore, Pietrusza, and Sommer [4] reported that when triethylsilane was boiled for 10 hours with diethylchlorosilane in 1:1 molar ratio in the presence of 0.8 mole-% anhydrous $AlCl_3$ the following reaction occurred:

$$(C_2H_5)_3SiH + (C_2H_5)_2SiCl_2 \xrightarrow{AlCl_3} (C_2H_5)_3SiCl + (C_2H_5)_2SiHCl + (C_2H_5)_2SiH_2 \qquad (4)$$

The yields of $(C_2H_5)_3SiCl$, $(C_2H_5)_2SiHCl$, and $(C_2H_5)_2SiH_2$ were 90, 44, and 43% respectively.

Inasmuch as we had found that dialkylchlorosilanes in the presence of $AlCl_3$ readily enter into a combined hydrogenation-halogenation reaction, it seemed possible to carry out reaction (4) under conditions that excluded the formation of $(C_2H_5)_2SiHCl$. Actually, when a mixture of triethylsilane and diethylchlorosilane in the molar ratio 2:1 was fractionally distilled in the presence of 1 mole-% of $AlCl_3$, the reaction proceeded quantitatively

$$2(C_2H_5)_3SiH + (C_2H_5)_2SiCl_2 \xrightarrow{AlCl_3} (C_2H_5)_2SiH_2 + 2(C_2H_5)_3SiCl \qquad (5)$$

The yields of the reaction products were 53 and 98% respectively. The yield of the easily volatile diethylsilane could be substantially improved by introducing an efficient trap into the system.

It must be noted that reaction (5) is general in character and is a new and rapid method for the preparation of alkylsilanes R_nSiH_{4-n} from the corresponding alkylchlorosilanes R_nSiCl_{4-n} (n= 1-3) by the reduction of the latter with trialkylsilanes in the presence of $AlCl_3$, which will be further illustrated in a number of other examples.** The trialkylsilane necessary for the reaction can easily be prepared under laboratory conditons. The trialkylsilane necessary for the reaction can easily be prepared under laboratory conditions. The trialkylchlorosilanes that are formed in reaction (5) in addition to the alkylsilanes are valuable starting materials for various organosilicon syntheses.

EXPERIMENTAL

Starting reagents. The following method seemed to be the most successful for the preparation of diethyl-, methyl-n-propyl-, and methyl isopropylchlorosilane. An ether solution of the Grignard reagent RMgBr (R= C_2H_5, n-C_3H_7 or iso-C_3H_7) was slowly added to one and one-half times the calculated amount of $RSiHCl_2$ (R=CH_3, C_2H_5) dissolved in ether, with vigorous stirring and external cooling of the reaction mixture. The magnesium salt that precipitated was filtered off on a Buchner funnel and after the excess ether (and also the unreacted CH_3SiHCl_2) had been distilled off, the reaction mixture was subjected to fractional distillation on a column with an efficiency of 20 theoretical plates. The yield of pure dialkylchlorosilanes was 28-32%.*** Along with them the corresponding trialkylsilanes (with the exception of methyldiisopropylsilane) also were formed in considerable amount.

Triethylsilane was prepared by the reaction of C_2H_5MgBr with $C_2H_5SiHCl_2$ in the molar ratio 2:1. The yield was 55-70%.

Diethylchlorosilane was obtained by repeated distillation of the fraction with b.p. 126-130° which was separated by fractional distillation of the mixture of ethylchlorosilanes prepared by "direct synthesis," and also of the product obtained by the disproportionation of diethylchlorosilane.

The properties of the starting materials are given in the Table.

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* In publication [3] it is shown that when SiH_4 and ethylene react at 400°, methylpropylsilane and methylethylsilane are formed, which, however, were not isolated individually.

** Some other organosilicon compounds containing Si-H bonds can be used as well as the trialkylsilanes.

*** Emeleus and Robinson [5] prepared $(C_2H_5)_2SiHCl$ starting with $HSiCl_3$, in 19% yield. Methyl-n-propyl-and methylisopropylchlorosilane are not described in the literature.

Properties of Starting Materials and Compounds Prepared

Numbers	Compound	Boiling point	n_D^{20}	d_4^{20}	MR_D		Elementary analysis (%)			
							H (—Si)		Cl	
					found	calculated	found	calculated	found	calculated
(I)	$(C_2H_5)_2SiHCl$	100.7°	1.4152	0.8895	34.55	34.67	—	—	26.79, 26.81	28.9
(II)	$CH_3(n.-C_3H_7)SiHCl$ *	95.9	1.4098	0.8796	34.54	34.67	—	—	26.97, 27.22	28.9
(III)	$CH_3(iso.-C_3H_7)SiHCl$ *	90.6	1.4173	0.8928	34.57	34.67	—	—	29.13, 29.28	28.9
(IV)	$(C_2H_5)_2SiH_2$	55.7	1.3916	0.6837	30.70	30.73	2.21	2.28	—	—
(V)	$CH_3(n-C_3H_7)SiH_2$ *	53.6	1.3857	0.6798	30.46	30.73	2.28	2.28	—	—
(VI)	$CH_3(iso-C_3H_7)SiH_2$ *	51.7	1.3789	0.6697	30.44	30.73	2.24	2.28	—	—
(VII)	$(C_2H_5)_2SiCl_2$	128.2	1.4307	1.0475	38.80	38.80	—	—	44.82, 44.92	45.13
(VIII)	$CH_3(n.-C_3H_7)SiCl_2$	124.4	1.4250	1.0351	38.89	38.80	—	—	44.90, 45.03	45.13
(IX)	$CH_3(iso-C_3H_7)SiCl_2$ *	121.2	1.4270	1.0385	38.84	38.80	—	—	44.85, 45.07	45.13
(X)	$(C_2H_5)_3SiH$	107.5	1.4120	0.7316	39.55	39.76	—	—	—	—
(XI)	$(C_2H_5)_3SiCl$	146.8	1.4308	0.8885	43.89	43.80	—	—	22.76, 22.97	23.52

Aluminum chloride – anhydrous, purified preparation.

Reactions of Dialkylchlorosilanes With Aluminum Chloride

Reaction of diethylchlorosilane with AlCl$_3$. a) 30.9 g of (C$_2$H$_5$)$_2$-SiHCl (I) was distilled from a small flask with a herring-bone dephlegmator over 3.1 g (9.2 mole-%) of AlCl$_3$. When the distillate was fractionally distilled on a rectifying column, we obtained 3.8 g of (C$_2$H$_5$)$_2$SiH$_2$ (IV) with b.p. 54-57° (44.2%); 7.0 g of unreacted (C$_2$H$_5$)$_2$SiHCl (22.7% of starting amount); and 12.3 g of (C$_2$H$_5$)$_2$SiCl$_2$ (VII) with b.p. 127-129° [80.4% calculated on the basis of the (C$_2$H$_5$)$_2$SiHCl that had reacted according to equation (1)]. The conversion of diethylchlorosilane was 77.3%.

b) 29.4 g of (C$_2$H$_5$)$_2$SiHCl was distilled over 6.4 (20 mole-%) of AlCl$_3$. When the distillate was fractionally distilled, we obtained 1.0 g (25.6%) of (C$_2$H$_5$)SiH$_2$, 1.9 g (6.4% of the starting amount) of unreacted diethylchlorosilane, 13.3 g (94.5%) of (C$_2$H$_5$)$_2$SiCl$_2$, and 6.8 g of (C$_2$H$_5$)$_3$SiCl (XI) with b.p. 143-147° (% Cl 22.63; calculated for C$_6$H$_{15}$SiCl 23.52) [100% calculated on the basis of the (C$_2$H$_5$)$_2$SiHCl that had reacted according to equation (3)]. The conversion of diethylchlorosilane was 93.6%.

Reaction of methylpropylchlorosilane with AlCl$_3$. 20.5 g of CH$_3$(C$_3$H$_7$)SiHCl (II) was distilled from a small flask with a dephlegmator over 1.8 g (8.1 mole-%) of AlCl$_3$. When the distillate was fractionally distilled, we obtained 3.0 g (56.3%) of CH$_3$(C$_3$H$_7$)SiH$_2$ (V) with b.p. 51-55°, 5.8 g (28.3% of the starting amount) of unreacted methylpropylchlorosilane, and 7.4 g of CH$_3$(C$_3$H$_7$)SiCl$_2$ (VIII) with b.p. 122-125° [78.8% calculated on the basis of the CH$_3$(C$_3$H$_7$)SiHCl that had reacted according to reaction (1)]. The conversion of methylpropylchlorosilane was 71.7%.

Reaction of methylisopropylchlorosilane with AlCl$_3$. a) 36.4 g of CH$_3$[(CH$_3$)$_2$CH]SiHCl (III) was distilled from a small flask with a dephlegmator over 4.0 g (10.1 mole-%) of AlCl$_3$. When the distillate was fractionally distilled, we obtained 3.7 g (48.3%) of CH$_3$[(CH$_3$)$_2$CH]SiH$_2$ (VI) with b.p. 50-54°, 14.8 g (40.8% of the starting material) of unreacted methylisopropylchlorosilane, and 12.9 g of CH$_3$[(CH$_3$)$_2$CH]SiCl$_2$ (IX) with b.p. 118-122° [94.4% calculated on the basis of the CH$_3$[(CH$_3$)$_2$CH]SiHCl that had reacted according to equation (1)]. The conversion of methylisopropylchlorosilane was 59.2%.

b) In a repeated experiment a mixture consisting of 36.8 g of CH$_3$[(CH$_3$)$_2$CH]SiHCl and 4 g of AlCl$_3$ was placed in a small flask connected to a rectifying column. By fractional distillation of the mixture we obtained 1.7 g (20.3%) of methylisopropylsilane with b.p. 51-53°, 12.9 g (35% of the starting amount) of unreacted methylisopropylchlorosilane, and 13.2 g of methylisopropyldichlorosilane with b.p. 120-121° [86.4% calculated on the basis of the CH$_3$[(CH$_3$)$_2$CH]SiHCl that had reacted according to equation (1)].

The conversion of methylisopropylchlorosilane in the instance cited was 65.%. The low yield of methylisopropylsilane was related to its exceptional volatility.

Reaction of diethyldichlorosilane with AlCl$_3$. 85.3 g of (C$_2$H$_5$)$_2$-SiCl$_2$ and 14.5 g (20.0 mole-%) of AlCl$_3$ were placed in a small flask equipped with a bulb condenser and a thermometer. The mixture was boiled for 31 hours. After the mixture was cooled, it was filtered off from the AlCl$_3$ and subjected to fractional distillation on a column. 82 g of product (96.2% of the starting diethyldichlorosilane) boiling in the range 127.5-129.5° (754 mm) was obtained.

Reduction of diethyldichlorosilane with triethylsilane in the presence of AlCl$_3$. a) 31.4 g of diethyldichlorosilane was added over a period of 2 hours to a boiling mixture of 45.5 g of (C$_2$H$_5$)$_3$SiH (X) and 0.8 g of anhydrous AlCl$_3$ in a three-necked flask equipped with a reflux condenser, thermometer, and dropping funnel. The mixture was boiled for 2.5 hours more until a constant boiling point was reached (116°). By fractional distillation of the reaction mixture on a column we obtained 4.5 g (25.6%) of (C$_2$H$_5$)$_2$SiH$_2$ (IV) with 55-56° and 59.1 g (98% of (C$_2$H$_5$)$_3$SiCl (XI) with b.p. 145-147.5°. The starting materials reacted completely.

b) A mixture of 38.2 g of (C$_2$H$_5$)$_3$SiH, 0.68 g of AlCl$_3$, and 25.8 g (0.164 g-mole) of (C$_2$H$_5$)$_2$SiCl$_2$ was placed in a small flask connected to a rectifying column and was subjected to distillation. 7.6 g (52.8%) of diethylsilane with b.p. 54-56° and 48.7 g (98.1%) of triethylchlorosilane with b.p. 146-147° were obtained. The starting materials reacted completely. The experiment lasted 2.5 hours.

SUMMARY

1. Upon distillation of dialkylchlorosilanes with 8-10 mole-% of AlCl$_3$ a disproportionation reaction takes

place which results in the formation of dialkylsilanes and dialkyldichlorosilanes. The reaction is a new, convenient method for the preparation of dialkylsilanes.

2. The reaction of diethylchlorosilane with 20 mole-% of $AlCl_3$ is accompanied by more deep-seated transformations. The reaction products contain triethylchlorosilane as well as diethylsilane and diethyldichlorosilane.

3. Methyl-n-propylchlorosilane, methylisopropylchlorosilane, methylisopropyldichlorosilane, methyl-n-propylsilane, and methylisopropylsilane have been prepared for the first time. The last two compounds are the first representatives of dialkylsilanes of the series $RR'SiH_2$.

4. The reduction, catalyzed by $AlCl_3$, of alkylchlorosilanes R_nSiCl_{4-n} to the corresponding alkylsilanes R_nSiH_{4-n} (n=1-3) with the aid of trialkylsilanes R_3SiH is a new, rapid, and convenient method for the synthesis of alkylsilanes.

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PHOTOCHEMICAL CHLORINATION OF ETHYLFLUOROSILANES

THE ORIENTING EFFECT OF FLUOROSILYL GROUPS

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The orienting and stabilizing effect of chlorosilyl groups in the chlorination and other reactions of organosilicon compounds has already been discussed by us repeatedly [1-4]. Fluorosilyl groups have scarcely been studied in this connection, unless we consider the work of Sommer, Bailey, Strong, and Whitmore [5]. These authors subjected triethylfluorosilane to chlorination with sulfuryl chloride in the presence of benzoyl peroxide; the α- and β-chloroethyldiethylfluorosilanes formed were investigated with respect to the action of alkali. Study of the effect of fluorine atoms attached to Si on the position and reactivity of the bonds in alkyl and aryl radicals connected to such fluorosilyl groups presents great interest. Fluorine considerably exceeds chlorine in the magnitude of its electronegativity (F– 4.0, Cl –3.0). The transition from compounds with one Si-F bond to compounds with three Si-F bonds is accompanied by a considerably greater increase in the dipole moment of the molecule as a whole than in the case of the corresponding compounds containing Si-Cl bonds [6]. Steric factors are less in the case of the Si-F bonds than of the Si-Cl bonds. It is known how strong an effect the fluoro-, difluoro-, and especially the trifluoromethyl group have on the reactivity of neighboring bonds. Thus, upon chlorination of $F_3CCH_2CH_3$ just the C-H bonds of the methyl group are chlorinated at first, and only afterward, under more severe conditions, the C-H bonds of the methylene group [7]. Here as in other cases (chlorination of $CF_3C_6H_5$ etc.) the orienting effect of the CF_3 group distinctly appears. In the dehydrochlorination of 1,1,1-trifluoro-2-chloropropane and 1,1,1-trifluoro-3-chloropropane, the CF_3 group shows a distinct stabilizing effect on the C - C bonds [8]. The orienting and stabilizing effect of the $-SiF_3$, $=SiF_2$, and $\equiv SiF$ groups in corresponding reactions of organosilicon compounds naturally may be less, if we take into account that the larger electron shell of silicon in comparison with that of carbon will weaken to a greater degree the transmission of such an effect to neighboring bonds. However, in comparison with chlorosilyl groups the effect of fluorosilyl groups may obviously be greater in compounds of similar structure, with correspondingly smaller steric factors.

In the chlorination of ethylfluorosilanes – triethylfluorosilane, diethyldifluorosilane, and ethyltrifluorosilane – we might expect less augmentation of the β-orienting effect of the fluorosilyl groups than in the ethylchlorosilanes – triethylchlorosilane, diethyldichlorosilane, and ethyltrichlorosilane. For the purpose of verifying this assumption, diethyldifluorosilane and ethyltrifluorosilane were prepared and chlorinated. Triethylfluorosilane had previously been chlorinated [5] with sulfuryl chloride in the presence of benzoyl peroxide. It thus was possible to obtain sufficiently clear data on the proportion of α-and β-chloroethyldiethylfluorosilanes formed. As regards diethyldifluorosilane and especially ethyltrifluorosilane, the use of this method, as a result of the low boiling points of the starting fluorides, scarcely could yield sufficiently satisfactory results, since chlorination with sulfuryl chloride of even tetramethylsilane, which is higher boiling (+28°) than ethyltrifluorosilane (–5°), was not successful. As a result of this, the chlorination of diethyldifluorosilane and ethyltrifluorosilane was carried out with chlorine in an apparatus that provided for the escape of the chlorination products from the reaction zone under conditions previously described [1,2,4,9]. The results of the chlorination are presented in Figs. 1 and 2 and in comparison with the data for the chlorination of the ethylchlorosilanes in Table 1.

From the data presented it is apparent that the β-orienting effect of the fluorosilyl groups is augmented to a greater degree by an increase in the number of fluorine atoms on the Si than the corresponding effect of chlorosilyl groups. This is fully explainable if we take into account the considerably greater electronegativity of the fluorine atom in comparison with that of chlorine.

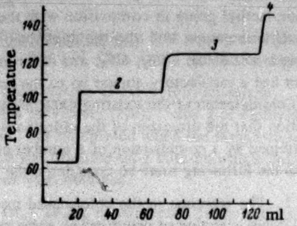

Fig.1. Distillation curve of chlorination products of $(C_2H_5)_2SiF_2$.
1) $(C_2H_5)_2SiF_2$, 2) $C_2H_5Si(F)_2CHClCH_3$,
3) $C_2H_5Si(F)_2CH_2CH_2Cl$,
4) $C_2H_5Si(F)_2C_2H_3Cl_2$

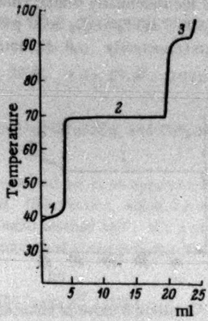

Fig. 2. Distillation curve of chlorination products of $C_2H_5SiF_3$.
1) $F_3SiCHClCH_3$, 2) $F_3SiCH_2CH_2Cl$,
3) $F_3SiC_2H_3Cl_2$.

TABLE 1

Starting compound	Monochlorides formed	Proportion of α- and β- -isomers	Chlorinating agent
$(C_2H_5)_3SiF$	$(C_2H_5)_2Si(F)CHClCH_3$ $(C_2H_5)_2Si(F)CH_2CH_2Cl$	1 : 0.8	SO_2Cl_2 [5]
$(C_2H_5)_2SiF_2$	$C_2H_5Si(F)_2CHClCH_3$ $C_2H_5Si(F)_2CH_2CH_2Cl$	1 : 1.2	Cl_2 *
$C_2H_5SiF_3$	$F_3SiCHClCH_3$ $F_3SiCH_2CH_2Cl$	1 : 4.4	Cl_2 *
$(C_2H_5)_3SiCl$	$(C_2H_5)_2Si(Cl)CHClCH_3$ . . . . $(C_2H_5)_2Si(Cl)CH_2CH_2Cl$	1 : 0.8 1 : 0.7	SO_2Cl_2 [5] Cl_2 [1]
$(C_2H_5)_2SiCl_2$	$C_2H_5Si(Cl)_2CHClCH_3$ . . . . $C_2H_5Si(Cl)_2CH_2CH_2Cl$	1 : 1.7 1 : 1.1	SO_2Cl_2 [10] Cl_2 [1]
$C_2H_5SiCl_3$	$Cl_3SiCHClCH_3$ . . . . $Cl_3SiCH_2CH_2Cl$	1 : 2.5 1 : 1.6	SO_2Cl_2 [11] Cl_2 [1]

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* Data from present investigation.

Inspection of the distillation curves in Figs. 1 and 2 makes evident the formation of dichlorides, the structure of which it was difficult to prove because of the small quantities of them. This question can be answered to some extent by the data on the chlorination of such compounds as β-chloroethyltrichlorosilane, 1,1,1,3-tetrachloropropane, and α-chloroethyltrichlorosilane, the tendencies in the chlorination of which it is easy enough to discover. α-Chloroethyltrichlorosilane upon chlorination either with chlorine [4] or with sulfuryl chloride [10] yields a mixture of dichlorides – α,α-dichloroethyltrichlorosilane and α,β-dichloroethyltrichlorosilane. β-Chloroethyltrichlorosilane upon chlorination with sulfuryl chloride yields only β,β-dichloroethyltrichlorosilane [10]. As we have established, upon chlorination with chlorine there appears along with β,β-dichloroethyltrichlorosilane, which is formed in overwhelming amount, a very small quantity of the α,β-isomer, which can be judged on the basis of the deflection in the distillation curve of the chlorination products of β-chloroethyltrichlorosilane (Fig. 3).

Taking into account the presence in the chlorination products of diethyldifluorosilane and ethyltrifluorosilane of a large amount of the β-chlorides compared to the α-chlorides, and also the indicated nature of the chlorination of the structurally similar chlorosilanes, it may be assumed that the dichlorides formed on chlorination of $(C_2H_5)_2SiF_2$ and $F_3SiC_2H_5$ most probably are β,β-dichloroethylfluorosilanes, possibly with an admixture of other isomers (principally α,β-dichlorides).

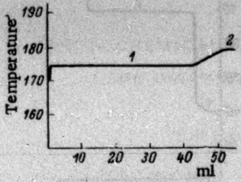

Fig. 3. Distillation curve of chlorination products of $Cl_3SiCH_2CH_2Cl$.
1) $Cl_3SiCH_2CHCl_2$, 2) $Cl_3SiCHClCH_2Cl$

The question of the preferential chlorination of the chloromethyl group in comparison with the methyl and methylene groups, and also the question of the orienting effect of the $SiCl_3$, SiF_3, and other groups, have not had a satisfactory answer up to the present time. Consideration of the existing data permits the assumption that the direction of the chlorination process is determined by a combination of a number of factors, of which the following must be considered the foremost.

1. The presence in the chlorinated molecule of polar bonds, capable of orienting by some means the molecule of the chlorinating agent with respect to these polar parts of the chlorinated molecule.

2. The position of the C-H bonds, which are weakened or strengthened uner the influence of the neighboring groups or atoms (halogens in this relation lead to a strengthening of the C-H bonds [12]).

3. The proportion and concentration of the atoms leading to the chlorination and the positive ions of chlorine, which are determined not only by the reaction conditions (activators and chlorination catalysts, temperature, medium, etc.), but also by the polarity of the chlorinated molecule.

4. Steric hindrances.

However, detailed consideration of these questions leads beyond the scope of this communication and requires special investigation.

TABLE 2

Formula of compound	Boiling point	Pressure (mm)	d_4^{20}	n_D^{20}	MR_D^{**}	
					found	calculated
$C_2H_5Si(F)_2CHClCH_3$ . . .	103.2°	753.2	1.1155	1.3790	32.86	32.24
$C_2H_5Si(F)_2CH_2CH_2Cl$ . . .	125.5	751.1	1.1467	1.3900	32.79	32.24
$C_2H_5Si(F)_2C_2H_3Cl_2$	148.2	751.1	1.3099	1.4207	37.36	37.08
$C_2H_5Si(F)_2CH=CH_2$ . . .	56.0	742.0	0.9578	1.3346	26.35	26.93
$F_3SiCHClCH_3$	39—39.5	749.5	1.2606	1.3180	23.25	21.54
$F_3SiCH_2CH_2Cl$	68.5	749.5	1.3661	1.3418	22.90	21.54
$F_3SiC_2H_3Cl_2$	91.7—92.0	749.5	1.5007	1.3750	27.92	26.38

Note. * Refraction of Si-F bond taken as equal to 1.50 [13].

In conclusion we consider the dehydrochlorination of α-chloroethylethyldifluorosilane and β-chloroethylethyldifluorosilane with quinoline. The previously noted difference [3] in the ease of dehydrochlorination of structurally similar α- and β-chloroethylethyldichlorosilanes is even more noticeable for the above-mentioned fluorosilanes, β-chloroethylethyldifluorosilane, in distinction to β-chloroethylethyldichlorosilane, on heating with quinoline considerably more easily undergoes decomposition* with the evolution of gaseous and liquid products, among which the presence of ethyltrichlorosilane and vinylethyldichlorosilane has been established. Vinylethyldifluorosilane was not detected in this reaction. In its turn α-chloroethylethyldifluorosilane is still more resistant than α-chloroethylethyldichlorosilane to dehydrochlorination with quinoline, since about 1/3 of the starting α-chloride is recovered from this reaction, and vinylethyldifluorosilane is formed only in insignificant yield.

The physical properties of the fluorosilanes prepared are given in Table 2.

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* The decomposition of β-chloroethylethyldifluorosilane proceeds very vigorously, in contrast to β-chloroethylethyldichlorosilane, and judging by the reaction products isolated, considerably more complexly, since it is accompanied by a side reaction replacing fluorine by chlorine.

EXPERIMENTAL

Diethyldifluorosilane was prepared from diethyldichlorosilane (394 g) and hydrofluoric acid under the conditions described by Eaborn [14], in the amount of 150 g (48%).

B.p. 61.5-62° (742.5 mm), d^{20}_4 0.9357, n^{20}_D 1.3398, MR_D 27.80; calc. 27.40. Literature data [14]: b.p. 62.5°.

Ethyltrifluorosilane was prepared in the amount of 63 g by heating $C_2H_5SiCl_3$ and CoF_2 in isooctane, while stirring. B.p. -5° (741 mm). Literature data [5]: b.p. -4.2°.

Chlorination of diethyldifluorosilane. The chlorination was carried out in an apparatus that has been described previously [1,9]. 150 g of diethyldifluorosilane was used. Chlorination, which was continued for 27 hours, was completed when the temperature in the pot of the column reached 110°. 156 g of chlorination products was distilled on a column which had an efficiency of 35 theoretical plates (Fig.1). The following fractions were obtained:

1st. 19.2 g of unreacted diethyldifluorosilane, b.p. 62.5° (755 mm), n^{20}_D 1.3392.

2nd. 50.4 g (30%) of α-chloroethylethyldifluorosilane, b.p. 103.2° (753.2 mm), d^{20}_4 1.1155, n^{20}_D 1.3790.

Found %: C 30.54, 30.30; H 5.82, 5.74. $C_4H_9ClF_2Si$.
Calculated %: C 30.28; H 5.72.

3rd. 58.5 g (35%) of β-chloroethylethyldifluorosilane, b.p. 125.5°, (751.1 mm), d^{20}_4 1.1467, n^{20}_D 1.3900.

Found %: C 30.30, 29.87; H 5.79, 5.75; F 22.82, 23.15. $C_4H_9ClF_2Si$.
Calculated %: C 30.28; H 5.72; F 23.95.

4th. 5 g of dichloroethylethyldifluorosilane, b.p. 148.2° (751.1 mm), d^{20}_4 1.3099, n^{20}_D 1.4207.

Found %: F 19.49, 20.67. $C_4H_8Cl_2F_2Si$.
Calculated %: F 19.68

Chlorination of ethyltrifluorosilane. Chlorination of 61 g of $C_2H_5SiF_3$ was carried out in an apparatus similar to that used for the chlorination of diethyldifluorosilane and having supplementary vacuum jackets, cooling the head of the column with a mixture of acetone and solid carbon dioxide. The head and cap part of the column were connected to a quartz tube (chlorination zone) which was exposed to the light of a PRK-2 quartz lamp. The HCl evolved passed through a trap that was cooled with the same mixture. The rest of the chlorination conditions were similar to those described earlier [1,9]. The chlorination, which lasted for 7.5 hours, was terminated when the temperature in the pot reached +40°. After distilling off the gaseous portion, the chlorination products were fractionally distilled on a column of 35 theoretical plates. The following fractions were obtained:

1st. 9.2 g of unreacted ethyltrifluorosilane, b.p. -4°.

2nd. 5 g (7.4%) of α-chloroethyltrifluorosilane, b.p. 39.5° (749.5 mm), d^{20}_4 1.2606, n^{20}_D 1.3180.

Found %: F 39.89, 39.07. $C_2H_4ClF_3Si$.
Calculated %: F 38.37.

3rd. 21.9 g (32.4%) of β-chloroethyltrifluorosilane, b.p. 68.5° (749.5 mm), d^{20}_4 1.3661, n^{20}_D 1.3418.

Found %: C 16.29, 16.34 H 2.74, 2.64; F 38.67, 38.26. $C_2H_4ClF_3Si$.
Calculated %: C 16.17; H 2.71; F 38.37.

4th. 6 g of dichloroethyltrifluorosilane, b.p. 91.7-92° (749.5 mm), d^{20}_4 1.5007, n^{20}_D 1.3750.

Found %: F 30.89, 29.65. $C_2H_3Cl_2F_3Si$.
Calculated %: F 31.14.

Chlorination of α-chloroethyltrichlorosilane. 192.5 g of α-chloroethylrichlorosilane was chlorinated up to a temperature of 179° for 8 hours under the conditions described above. 171.4 g of chlorination products were distilled on the column. The following fractions were obtained.

1st. 47.4 g (20.9%) of α,α-dichloroethyltrichlorosilane, b.p. 152° (732 mm), m.p. 109-111°. Literature data [10]: b.p. 152° (734 mm), m.p. 112-114°.

2nd. 39.5 g (17.4%) of α,β-dichloroethyltrichlorosilane, b.p. 179° (732 mm), d_4^{20} 1.5207, n_D^{20} 1.4835, MR_D 43.68; calc. 43.48. Literature data [10]: b.p. 182° (739 mm).

Chlorination of β-chloroethyltrichlorosilane. 136 g of β-chloroethyltrichlorosilane was chlorinated up to a temperature of 179° for 31 hours. 160 g of chlorination products were distilled on the column in vacuo. The following fractions were obtained:

1st. 11.4 g of starting material; b.p. 48.5° (17 mm), n_D^{20} 1.4655.

2nd. 75.2 g (51.5%) of a mixture of β,β- and α,β-dichloroethyltrichlorosilanes, b.p. 69° (18 mm), d_4^{20} 1.5236, n_D^{20} 1.4808.

3rd. 6. 4 g (4.4%) of a mixture of trichloroethyltrichlorosilanes, b.p. 80.5° (17mm), d_4^{20}, 1.5908, n_D^{20} 1.4910.

The dichlorides were subjected to repeated distillation on the same column at atmospheric pressure. As seen from the distillation curve for the mixture of dichlorides (Fig. 3), principally β,β-dichloroethyltrichlorosilane was present.

B.p. 174.5° (742.5 mm), d_4^{20} 1.5214, n_D^{20} 1.4798, MR_D 43.37; calc. 43.48. Literature data [10]: b.p. 172° (739 mm).

α,β-Dichloroethyltrichlorosilane with b.p. 180° (750 mm) and n_D^{20} 1.4844 was present in the mixture in very small amount, as can be judged from the same curve. Upon chlorination of β-chloroethyltrichlorosilane with sulfuryl chloride, as is known [10], exclusively β,β-dichloroethyltrichlorosilane is produced. The appearance of α,β-dichloroethyltrichlorosilane upon chlorination with chlorine might have been expected [1].

Chlorination of 1,1,1,3-tetrachloropropane. 115 g of material was chlorinated up to a temperature of 184° for 32 hours in the same apparatus. From 134 g of chlorination products the following fractions were separated after distillation on the column in vacuo.

1st. 7.3 g of starting 1,1,1,3-tetrachloropropane, b.p. 58.7° (24 mm), n_D^{20} 1.4836, d_4^{20} 1.4632.

2nd. 59.7 g (46.1%) of 1,1,1,3,3-pentachloropropane, b.p. 79° (24 mm), d_4^{20} 1.5736, n_D^{20} 1.4980, MR_D 40.30; calc. 40.22.

3rd. 18.5 g (14.3%) of 1,1,1,2,3-pentachloropropane, b.p. 85.5-86° (21 mm), d_4^{20} 1.6064, n_D^{20} 1.5078, MR_D 40.12; calc. 40.22.

Dehydrochlorination of β-chloroethylethyldifluorosilane. For the reaction 35 g of the compound and 35 g of the quinoline were taken. When the mixture of the β-chloride and quinoline was heated, a vigorous evolution of gases occurred. After the evolution diminished, it was possible to distill off 9 g of liquid products, from which the following fractions were separated after distillation on the column.

1st. 3.1 g of ethyltrichlorosilane, b.p. 97° (742 mm), d_4^{20} 1.2395, n_D^{20} 1.4238, MR_D 33.64 calc. 33.80.

Determination of the constants of pure ethyltrichlorosilane gave the following results: b.p. 97° at 747 mm, d_4^{20} 1.2403, n_D^{20} 1.4251, MR_D 33.71; calc. 33.80.

2nd. 1.6 g with b.p. 119° (742 mm), d_4^{20} 1.0737, n_D^{20} 1.4420, which apparently was ethylvinyldichlorosilane. This was confirmed by the closeness of the constants of this fraction to those of pure ethylvinyldichlorosilane (b.p. 122-123°, d_4^{20} 1.07 6,* n_D^{20} 1.4410). The somewhat lower boiling point of the ethylvinyldichlorosilane obtained by the dehydrochlorination in comparison with pure ethylvinyldichlorosilane can be explained by slight decomposition of the residue in the pot of the rectifying column.

Dehydrochlorination of α-chloroethylethyldifluorosilane. 36 g of the compound was subjected to dehydrochlorination with 37 g of quinoline. The reaction proceeded very quietly. 22 g of a mixture of reaction products with b.p. 50-100° was distilled off, from which the following fractions were separated after distillation on the column.

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* As in original – Publisher's note.

1st. 1.5 g (5.3%) of ethylvinyldifluorosilane, b.p. 56° (742 mm), d^{420}*0.9578, n^{20}_D 1.3346.

Found %: C 38.84, 38.76; H 6.89, 6.82. $C_4H_8F_2Si$.
Calculated %: C 39.32; H 6.60.

2nd. 9.5 g of starting α-chloroethylethyldifluorosilane, b.p. 101-102° (742 mm), n^{20}_D 1.3789.

SUMMARY

1. It has been shown that as fluorine atoms accumulate on silicon in the series $(C_2H_5)_3SiF \rightarrow (C_2H_5)_2SiF_2 \rightarrow C_2H_5SiF_3$, a considerable strengthening of the β-orienting effect of the fluorosilyl groups occurs.

2. A distinct difference in the character of the dehyderochlorination of α- and β-chloroethylethyldifluorosilanes with quinoline has been established, which is connected, apparently, with the stabilizing effect of the fluorosilyl groups.

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*Probably d^{20}_4 - Publisher's note.

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SYNTHESIS OF ALKYLALKOXYACETOXYSILANES

K.A. Andrianov, A.A. Zhdanov, and A.A. Bogdanova

Recent investigations have shown [1] that alkylacetoxysilanes are capable of reacting with alcohols to form alkylalkoxyacetoxysilanes.

$$RSi(OCOCH_3)_3 + R'OH \longrightarrow RSi(OCOCH_3)_2(OR') + CH_3COOH$$

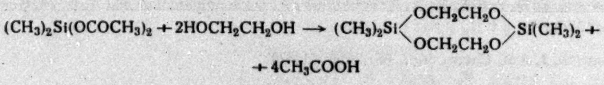
This reaction is of substantial interest as a method for the preparation of monomeric organosilicon compounds containing functional groups in the alkoxy radicals. As is well known, alkylalkoxysilanes usually are prepared by the action of alcohols on alkylhalogenosilanes or by alcoholysis by heating the higher alcohols with alkylethoxysilanes. In those instances when the alkoxy group to be introduced contains other reactive functional groups that react with the hydrogen halide that is produced as a by-product, the usual methods of preparation of alkylalkoxysilanes are unsuitable.

K. A. Andrianov and V. G. Dubrovina have shown [2] that alkylacetoxysilanes are easily alkylated by glycidol and that this reaction thus may be used successfully for the preparation of organosilicon monomers that contain epoxide groups in the alkoxy radical.

The object of the present investigation was the further study of this reaction applicable to alcohols containing saturated aliphatic radicals or unsaturated radicals with an active double bond, and also applicable to bivalent alcohols. As starting materials isoamyl alcohol, glycol, and monomethacrylic ester of glycol were used. For the alkoxylation methyltriacetoxysilane and dimethyldiacetoxysilane were used. The properties of the materials obtained are given in the table. These materials were synthesized by us according to the following schemes.

$$CH_3Si(OCOCH_3)_3 + C_5H_{11}OH \longrightarrow CH_3Si(OCOCH_3)_2(OC_5H_{11}) + CH_3COOH$$

$$CH_3Si(OCOCH_3)_3 + 2C_5H_{11}OH \longrightarrow CH_3Si(OCOCH_3)(OC_5H_{11})_2 + 2CH_3COOH$$



$$(CH_3)_2Si(OCOCH_3)_2 + 2HOCH_2CH_2OH \longrightarrow (CH_3)_2Si\left\langle\begin{matrix}OCH_2CH_2O\\OCH_2CH_2O\end{matrix}\right\rangle Si(CH_3)_2 + 4CH_3COOH$$

$$CH_3Si(OCOCH_3)_3 + CH_2{=}C(CH_3)COOCH_2CH_2OH \longrightarrow$$
$$\longrightarrow CH_3Si(OCOCH_3)_2OCH_2CH_2OCOC(CH_3){=}CH_2 + CH_3COOH$$

EXPERIMENTAL

Methyldiacetoxyisoamyloxysilane. To 65 g of methyltriacetoxysilane was added with stirring over a period of 25 minutes 26 g of isoamyl alcohol. The reaction mixture was heated during the introduction of the alcohol to 54°, then it was cooled by stirring for 1 hour. The reaction rproduct was fractionally distilled in vacuo; the following fractions were collected: 1st. 43-102° (10 mm), 17 g; 2nd 102-110° (10 mm), 53 g; residue 15 g. The 2nd fraction was redistilled at a temperature of 106-108° (10 mm) and was pure methyldiacetoxyisoamyloxysilane.

d_4^{20} 1.0220, n_D^{20} 1.4065, MR_D 59.74; calc. 60.34

Material	Boiling point	d_4^{20}	n_D^{20}	MR_D		Content (in %)					
						C		H		Si	
				found	calculated	found	calculated	found	calculated	found	calculated
Methyldiacetoxyisoamyloxysilane $CH_3Si(OCOCH_3)_2(OC_5H_{11})$	106—108° (10 мм)	1.0220	1.4065	59.74	60.34	47.89	48.73	8.03	8.12	11.88	11.30
Methylacetoxydiisoamyloxysilane $CH_3Si(OCOCH_3)(OC_5H_{11})_2$	129—130 (14 мм)	0.9269	1.4083	73.92	74.23	56.77	56.53	10.29	10.10	10.25	10.15
Cyclic ether of glycol and dimethyldiacetoxysilane	—	—	—	—	—	40.44	40.65	8.57	8.57	23.24	23.74
Methyldiacetoxy-2-methacrylethoxysilane $CH_3Si(OCOCH_3)_2OCH_2CH_2OCOC(CH_3)=CH_2$	133—134° (0.5 мм)	1.1516	1.4335	65.71	66.27	44.76	45.50	6.22	6.59	9.88	9.66

Found %: C 47.89; H 8.03; Si 11.88; $OCOCH_3$ 48.07. $C_{10}H_{20}O_5Si$.
Calculated %: C 48.73; H 8.12; Si 11.30; $OCOCH_3$ 47.58.

Methylacetoxydiisoamyloxysilane was prepared by a similar method from 65 g of methyltriacetoxysilane and 52 g of isoamyl alcohol. By fractional distillation of the reaction mixture the following fractions were obtained: 1st. 43-124° (30 mm), 29 g; 2nd 124-135° (25 mm), 4 g; 3rd 135-142° (24 mm), 41 g. The 3rd fraction was redistilled at 129-130° (14 mm) and was pure methylacetoxydiisoamyloxysilane.

d_4^{20} 0.9269, n_D^{20} 1.4083, MR_D 73.92; calc. 74.23.
Found %: C 56.77; H 10.29; Si 10.25; $OCOCH_3$ 21.82. $C_{13}H_{28}O_4Si$.
Calculated: C 56.53; H 10.10; Si 10.15; $OCOCH_3$ 21.37.

Cyclic ether of glycol and dimethyldiacetoxysilane was prepared by a similar method from 88 g of dimethyldiacetoxysilane and 31 g of ethyleneglycol. The following fractions were separated by distillation: 1st 40-60° (20 mm), 58 g; 2nd 60-85° (20 mm), 10 g; 3rd 85-130° (20 mm), 31 g; residue 12 g. The 3rd fraction when it was distilled started to crystallize in the condenser and at the end of the distillation crystals and a small amount of liquid had collected in the receiver. The crystals were filtered out and dried in a vacuum desiccator.

Found %: C 40.44; H 8.57; Si 23.24. $C_8H_{20}O_4Si$.
Calculated %: C 40.65; H 8.57; Si 23.74.

Monomethacrylic ester of glycol. In a three-necked flask with a stirrer, thermometer, reflux condenser, and funnel for the introduction of powdered material were placed 563.5 g of ethylenechlorohydrin and 8.5 g of cuprous chloride. The mixture was heated to 110-115° and at this temperature there was introduced into the flask 378 g of pulverized sodium methacrylate mixed with 8.5 g of cuprous chloride, over a period of 6-7 hours. Then the mixture was heated for another 6-7 hours at 115-120°, the precipitate of sodium chloride was filtered out, and the filtrate was fractionated in vacuo. The following fractions were obtained: 1st 40-99° (26 mm); 2nd 99-103° (26 mm); 3rd 103-110° (26 mm). For the following syntheses the 2nd fraction was used, which was monomethacrylic ester of glycol.

2-Methacrylethoxymethyldiacetoxysilane was prepared by the method described above with the sole difference that the acetic acid that was produced as a result of the alkoxylation was distilled off in vacuo and the residue was then fractionated. For the reaction 220 g of methyltriacetoxysilane and 130 g of monomethacrylic ester of glycol were used. When the reaction was completed, the acetic acid was distilled off in vacuo as a fraction with b.p. 40-50° (40 mm) in the amount of 63 g. Upon distillation of the residue the following fractions were collected: 1st 93-120° (0.5 mm); 2nd 120-128° (0.5 mm); 3rd 128-134° (0.5 mm). The 3rd fraction ws redistilled at 133-134° (0.5 mm) and was 2-methacrylethoxymethyldiacetoxysilane.

d_4^{20} 1.1516, n_D^{20} 1.4335, MR_D 65.71; calc. 66.27.
Found %: C 44.76; H 6.22; Si 9.88; $OCOCH_3$ 41.10. Saponification number 576.7. $C_{11}H_{18}O_7Si$.
Calculated %: C 45.50; H 6.59; Si 9.66; $OCOCH_3$ 40.67. Saponification number 579.7.

The product obtained was a colorless liquid, readily polymerized by heating in the presence of initiators and hydrolyzed by the action of water with the formation of polymeric products.

SUMMARY

The reaction of methyltriacetoxysilane with isoamyl alcohol and with the monomethacrylic ester of glycol and also the reaction of dimethyldiacetoxysilane with ethyleneglycol have been investigated. It has been shown that the reaction of the alcohols mentioned with alkylacetoxysilanes proceeds according to a general scheme with the formation of alkoxyderivatives and acetic acid.

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INVESTIGATIONS IN THE FIELD OF CONJUGATED SYSTEMS

LXXVII. THE ORDER OF ADDITION OF HYDROGEN HALIDES TO PROPENYLACETYLENE

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When hydrogen chloride or bromide is added to vinylacetylene in the absence of catalysts that cause an allyl rearrangement, good yields are obtained of 4-halogenobutadienes-1,2 (1-4-addition), which are capable of undergoing isomerization under the influence of the catalysts mentioned to 2-halogenobutadienes-1,3 [1-3].

The addition of hydrogen halides to the homologs of vinylacetylene, and especially to vinylalkyl- and isoalkenylacetylenes, has been studied sufficiently only in the presence of catalysts, where the formation has been established of 1,3-diene chlorides and bromides of the types $R{-}CH{=}CX{-}CH{=}CH_2$ and $CH_2{=}\underset{\substack{|\\R}}{C}{-}CX{=}CH_2$ [4-8]. The order of addition of hydrogen halides to the third possible type of near homologs of vinylacetylene – the alkenylacetylenes – has not been investigated.

In previous communications it has been shown that alkenylacetylenes add hydrogen at the triple bond [9] and bromine prodominantly in the 1,4-position [10]. With respect to the order of addition of bromine they differ distinctly from the vinylalkylacetylenes, which form acetylenic dibromides with bromine [11].

For the purpose of clarifying the basic rules of addition reactions of vinylacetylene hydrocarbons it was of interest to study the order of addition of hydrogen halides to alkenylacetylenes. In this communication the results of experiments on the reaction of propenylacetylene with hydrogen chloride and bromide are examined.

As the result of the addition of hydrogen halides to propenylacetylene the formation of the following six compounds might be expected:

$$R{-}CH{=}CH{-}CX{=}CH_2 \ \text{(I)} \quad R{-}CH{=}CH{-}CH{=}CHX \ \text{(II)},$$

$$R{-}CH_2{-}CH{=}C{=}CHX \ \text{(III)},$$

$$R{-}CHX{-}CH{=}C{=}CH_2 \ \text{(IV)}, \quad R{-}CH_2{-}CHX{-}C{\equiv}CH \ \text{(V)},$$

$$R{-}CHX{-}CH_2{-}C{\equiv}CH \ \text{(VI)}.$$

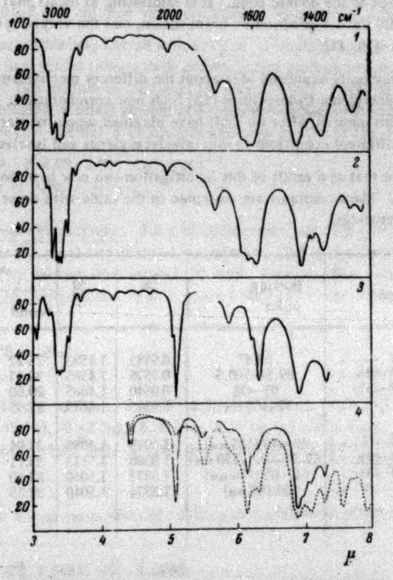
The hydrochloride and hydrobromide actually obtained boiled within a rather narrow temperature range, showed great stability toward alcoholic alkali, entered into a condensation reaction with naphthaquinone with the formation of products that were oxidized in alkaline solution by the oxygen of the air to 1-methyl-3-halogenoanthraquinones, and did not react with an ammoniacal solution of silver oxide. These chemical properties of the compounds obtained compelled us to reject as unacceptable all the possible formulas except formula (I).

Formula (I) was confirmed by a study of the infrared spectra of the hydrochloride and the hydrobromide. In these spectra the frequencies were absent that are characteristic of allene and terminal acetylene groups and, on the contrary, frequencies were present for a conjugated system of double bonds (6.18 and 6.25-6.30 μ) and the $CH_2{=}C$ group (ν_{CH} 3.20 and $\delta'_{CH=C}$ 11.18 and 11.34 μ). In the portion most sensitive to structural factors – the region 9.5-11.5 μ – the spectra of both halides were similar to the spectra of chloroprene and bromoprene and differed from the spectrum of 1-bromobutadiene (Fig. 1, curves 1 and 2) [12].

All these data left no doubt that the addition of hydrogen halides to propenylacetylene took place at the acetylenic bond in conformance with Markovnikov's rule, with the formation of 1,3 diene halides (I), i.e. differently than to vinylacetylene.

Since there were no reliable data in the literature on the order of addition of hydrogen halides to other homologs of vinylacetylene in the absence of catalysts, we set up orienting experiments on the hydrobromination of isopropenylacetylene and vinylethylacetylene. These experiments showed that under these conditions both hydrocarbons yielded compounds that differed from the hydrobromides previously investigated.

The product obtained as a result of addition of HBr to isopropenylacetylene boiled considerably higher than the previously described 3-bromo-2-methylbutadiene-1,3, lost about 50% bromine by the action of an alcoholic solution of KOH in the cold, and on ozonization gave a large amount of formaldehyde and bromoacetone. In its infrared spectrum there were found: an intense frequency of 5.09 μ, characteristic of an allene system, intense frequencies of 1,3-diene halogen derivatives (6.20 and 6.32 μ), and, of particular interest, frequencies of a terminal acetylene group (3.04 and 4.68 μ) (Fig. 1, curve 3).



Infrared absorption spectra.
1) hydrochloride of propenylacetylene, 2) hydrobromide of propenylacetylene, 3) mixture of hydrobromides of isopropenylacetylene, 4) mixture of hydrobromides of vinylethylacetylene obtained in the absence of catalysts (continuous line) and in the presence of catalysts (dotted line).

Thus, it appeared that isopropenylacetylene added HBr in the absence of catalysts by all three possible routes. The data obtained indicated that about 50% of the mixture was 1,3-diene hydrobromide (apparently

$CH_2{=}CCH_3{-}CBr{=}CH_2$). The larger part of the remainder was allene dibromide, apparently $CH_2Br{-}CCH_3{=}C{=}CH_2$.

The product obtained by the reaction of HBr with vinylethylacetylene also differed distinctly in physical and chemical properties from the 3-bromohexadiene-1,3 previously described [6]. By the action of alcoholic alkali in the cold it lost about 50% bromine, upon ozonization it yielded about 40% formaldehyde, and when heated with HBr and Cu_2Br_2 it was converted to the compound described as 3-bromohexadiene-1,3. These data permitted the conclusion that approximately 50% of the product of hydrobromination of vinylethylacetylene consisted of the latter pound. At the same time, in the infrared spectrum of the hydrobromide (figure, curve 4) there was an intense frequency 5.09μ, the appearance of which indicated that the material contained a considerable amount of allene hydrobromide, apparently $CH_3{-}CH_2CH{=}C{=}Ch{-}CH_2Br$. Besides this frequency there were present in the spectrum frequencies of the 1,3-diene system (6.14, 6.22, 6.32μ), and also of the acetylenic bond (doublet 4.41, 4.44μ).

The infrared spectrum of the material obtained by the action of HBr and Cu_2Br_2 on the starting mixture of hydrobromides differed from the spectrum of the starting material in the weakening of the frequency 5.09 μ and the strengthening of frequencies in the region 6-6.5 μ, which indicates the formation of 1, 3-diene hydrobromide at the expense of the allenic compound (figure, curve 4, dotted).

Thus, vinylethyl- and isopropenylacetylenes differed distinctly in the order of addition of hydrogen bromide from propenylacetylene, first, in the tendency to formation of the 1,4-product, and second, in the partial addition of hydrogen bromide to the double bond. It is interesting to recall that the alkenylacetylenes, on the other hand, yield principally the 1,4-products on bromination, and the vinylalkylacetylenes yield the 1,2 products (at the double bond) [10, 11].

Consequently, the previously expressed idea about the different mechanism of addition of bromine and hydrogen bromide to vinylacetylenic hydrocarbons [13] finds new corroboration. We propose to take up the detailed consideration of this question after we shall have obtained supplementary data on the order of addition of hydrogen halides under different conditions to vinylalkylacetylenes and isoalkenylacetylenes.

In conclusion we note that as a result of this investigation two new homologs of chloroprene and bromoprene have become known. Their constants are presented in the table with those of chloroprene, bromoprene, and previously described homologs.

Compound*	Boiling point	d_4^{20}	n_D^{20}	MR_D		EM_D
				found	calculated	
$CH_2{=}CCl{-}CH{=}CH_2$	59.4°	0.9583	1.4583	25.22	24.60	0.40
$CH_3{-}CH{=}CCl{-}CH{=}CH_2$	99.5—100.5	0.9576	1.4785	30.34	29.22	1.11
$CH_2{=}CCl{-}CH{=}CH{-}CH_3$	97—98	0.9640	1.4685	29.60	29.22	0.38
$CH_2{=}CCl{-}\underset{\substack{\vert \\ CH_3}}{C}{=}CH_2$	37 (105 мм)	0.9543	1.4689	29.93	29.22	0.71
$CH_2{=}CBr{-}CH{=}CH_2$	42—43 (165 мм)	1.3970	1.4988	27.94	27.50	0.44
$CH_3{-}CH{=}CBr{-}CH{=}CH_2$	67.5—68.5 (120 мм)	1.3308	1.5113	33.11	32.12	0.99
$CH_2{=}CBr{-}CH{=}CH{-}CH_3$	64—65 (120 мм)	1.3273	1.5040	32.80	32.12	0.68
$CH_2{=}CBr{-}\underset{\substack{\vert \\ CH_3}}{C}{=}CH_2$	35 (40 мм)	1.3374	1.5040	32.55	32.12	0.43

* The data for previously described materials are taken from the review article [14].

From the data in the table it is seen that the 2-halogenopentadienes-1,3 have lower boiling points and refractive indices than the 3-halogenopentadienes-1,3. In the series of isomeric halogenopentadienes-1,3 the 3 halogenopentadienes show the greatest exaltation of the molecular refraction.

EXPERIMENTAL

The methods of preparation and the constants of the vinylacetylenic hydrocarbons used in this investigation have been given in previous communications [11,12].

The infrared spectra were obtained in an IKS-2 spectrograph in the range 3-5.5 μ with a LiF prism and beyond that with a NaCl prism. Thickness of layer in all cases was 0.1 mm.*

Hydrochlorination of propenylacetylene.** 8.8 g of the hydrocarbon was shaken for 3 hours with 29 ml of hydrochloric acid (d 1.196). The reaction products together with the unreacted hydrocarbon were separated, washed with water, dried over $CaCl_2$, and distilled at ordinary pressure. In this way 2.7 g of monohydrochloride of 2-chloropentadiene-1,3 with b.p. 97-98° (other constants given in the table) and 2.5 g of the dihydrochloride were obtained.

Hydrochloride. Found %: Cl 34.49, 34.48. C_5H_7Cl.
Calculated %: Cl 34.57.

Infrared spectrum: 3.20 (m), 3.28 (s), 3.35(s), 3.39(s), 3.42(s), 3.49 (s), 3.67(w), 4.06(w), 4.98 (w), 5.00 (w), 5.69 (m), 6.08^{x}(s), 6.18 (s), 6.25 (s), 6.89 (s), 7.00^{x}(s), 7.74 (m), 8.23 (s), 8.35^{x}(s), 8.92 (s), 9.37^{x}(m), 9.66^{x}(m), 10.13^{x}(s), 10.42 (s), 11.34 (vs), 12.41 (m), 13.53 (s)μ (figure, curve 1).

(Frequencies are marked with x sign here and below that appeared in the spectrum as protrusions on more intense frequencies).

When 0.5566 g of the hydrochloride was heated with a double excess of 10 % KOH solution in methanol for 1 hour on a water bath, 0.0106 g of chlorine went into solution, constituting 5.5% of that in the sample.

When 1.0 g of the hydrochloride was heated with 1.4 g of α-naphthaquinone in 5 ml of toluene for 16 hours on a boiling water bath in a sealed tube, a dark-colored, tarry product was obtained. Air was passed through an alkaline solution of this product in methanol for several hours. From the precipitate obtained, which was in large part potassium chloride, a small amount of 1-methyl-3 chloroanthraquinone was extracted with ethyl acetate. Yellow needles of 1-methyl-3-chloroanthraquinone melted at 188-189° (decomp., uncorr.) [16].

Found %: C 69.94, 70.24, H 4.02, 3.93. $C_{15}H_9O_2Cl$.
Calculated %: C 70.18; H 3.53.

Hydrobromination of propenylacetylene. 9.8 g of hydrocarbon and 33.3 g of hydrobromic acid (d 1.74) were shaken for 5 hours. After the usual treatment of the mixture, 12.7 g of a fraction boiling up to 100° and 10 g of residue were obtained by vacuum distillation (120 mm). From the first fraction was separated 6.7 g of the monohydrobromide (2-bromopentadiene-1,3) with b.p. 64-65° (120 mm). The other constants are given in the table.

Found %: Br 54.31, 54.38. C_5H_7Br.
Calculated %: Br 54.36.

Infrared spectrum: 3.21^{x}(m), 3.28 (s), 3.35 (s), 3.39 (s), 3.42 (s), 3.51 (m), 3.67 (w), 3.94 (w), 4.06 (vw), 4.14 (w), 4.98 (w), 5.02 (w), 5.43 (w), 5.68 (m), 6.08^{x}(s), 6.17(s), 6.30 (s), 6.94(s), 7.10 (s), 7.26(s), 7.69 (w), 7.86 (m), 8.33 (s), 8.96 (s), 9.66^{x}(m), 10.21*(m), 10.48 (s), 11.18 (vs), 12.41 (m), 13.34 (s), 13.94 (s) μ (figure, curve 2).

By repeated distillations 3 g of the product of addition of 2 molecules of HBr to propenylacetylene was obtained from the residue.

B.p. 60-65° (10 mm), d_4^{20} 1.6681, n_D^{20} 1.5245.
Found %: Br 68.68, 68.89. $C_6H_8Br_2$.
Calculated %: Br 70.12.

When 0.5128 g of the hydrobromide was heated with a double excess of KOH in 5 ml of methanol for 1 hour on a boiling water bath, 0.056 g of bromine went into solution, or about 20% of that in the sample.

2.3 g of the hydrobromide and 2.2 g of α-naphthaquinone in 5 ml of toluene were heated on a boiling water bath in a sealed tube for 16 hours. The tarry reaction products were dissolved in methanol and oxidized in alkaline methanol solution by the oxygen of the air. From the precipitate was extracted about 1 g of greenish-yellow crystals, which were recrystallized from a mixture of chloroform and benzene.

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* The authors express their thanks to G. I. Semenov for assistance in the investigation of the infrared spectra.

** Mixture of cis- and trans-forms with the first predominant [15].

Yellow plates of 3-bromo-1-methylanthraquinone melted at 176-177°.

Found %: C 60.18, 60.28; H 3.38, 3.47; Br 26.96. $C_{15}H_9O_2Br$.
Calculated %: C 59.82; H 3.01; Br 26.54.

Hydrobromination of vinylethylacetylene. Upon shaking 20 g of the hydrocarbon with 33 g of hydrobromic acid (d 1.74) for 3 hours, a product was obtained which was separated by vacuum distillation (120 mm) into the following fractions: 1st, up to 94° – 10.5 g (starting hydrocarbon); 2nd, 94-104° — 4.9 g (isomeric hydrobromides); 3rd, 104-120° — 1.1 g; 4th — residue 5.5 g.

Isomeric hydrobromides: b.p. 94-104° (120 mm), d_4^{20} 1.2794, n_D^{20} 1.5070.
Found %: Br 49.87, 50.07. C_6H_9Br.
Calculated %: Br 49.62.

Infrared spectrum: 4.41(m), 4.44(m), 5.08(s), 5.47(w), 6.14(s), 6.22(m), 6.30(w), 6.87(s), 7.06(s), 7.27(s) μ (figure, curve 4).

By the action of a double excess of 10% KOH in methanol on 0.5544 g of hydrobromide for 2 hours in the cold, 0.147 g of bromine was split out, or about 46% of that in the sample.

The hydrobromide was subjected to ozonization for the purpose of determining the terminal CH_2 group. As a result of the ozonization and decomposition of the ozonides, there was obtained in the form of dinaphtholmethane in two samples 0.0048 and 0.0045 g of formaldehyde from 0.0634 g of starting hydrobromide. This amount of formaldehyde corresponds to a diene hydrobromide of 38 - 41%.

By heating the hydrobromide with concentrated hydrobromic acid and Cu_2Br_2 in ether solution for 6 hours, the hydrobromide previously described (chiefly 3-bromopentadiene-1,3) was obtained with b.p. 87-89° (10 mm), n_D^{20} 1.5060.

Infrared spectrum: 4.44(w), 5.09(w), 5.50(m), 6.14(s), 6.21^{x}(s), 6.32^{x}(s), 7.07(s), 7.28(s), 7.51(s), 7.72^{x}(s), 7.93(s)μ (figure, curve 4, dotted).

This spectrum was identical with that of the material obtained by the action of concentrated hydrobromic acid in the presence of Cu_2Br_2 on vinylethylacetylene.

Hydrobromination of isopropenylacetylene. 8.7 g of hydrocarbon was shaken for 3 hours with 12 g of hydrobromic acid (d. 1.74). 5.2 g of hydrobromide and 2.2 g of residue were obtained.

The following values were found for the mixture of isomeric hydrobromides after repeated distillation:

b.p. 42-48° (40 mm), d_4^{20} 1.3283, n_D^{20} 1.5058.

Found %: Br 54.24. C_5H_7Br.
Calculated %: Br 54.36.

Infrared spectrum: 3.04(m), 3.22(w), 3.35(s), 3.40(s), 3.44(s), 3.52(m), 3.69(w), 4.16(w), 4.33(w), 4.53(w), 4.68(w), 5.04(m), 5.09(s), 5.88(w), 6.20^{x}(w), 6.32(s), 6.90(s), 7.30(s) μ (figure, curve 3).

A sample of 0.5749 g of the hydrobromides upon standing in the cold with a double excess of 10% KOH in methanol lost 0.15 g of bromine, which constituted 48.4% of that in the sample.

By ozonization and decomposition of the ozonides in two samples corresponding to 0.068 g of material, 0.0070 and 0.0065 g of formaldehyde was obtained in the form of dinaphtholmethane, which corresponds to 46--50 mole-% per molecule of hydrobromide. Clearly bromoacetone was a principal part of the decomposition products of the ozonides, since the liquid had strong lachrymatory properties. The decomposition products of the ozonides were not investigated further.

SUMMARY

1. The order of addition of hydrogen chloride and bromide to propenylacetylene has been investigated.

2. It has been shown that in both instances the addition takes place on the triple bond with the formation of the corresponding 2-chloro- and 2-bromopentadienes-1,3.

3. In preliminary experiments it was established that under similar conditions (in the absence of catalysts) isopropenyl- and vinylethylacetylenes give mixtures of all possible addition products of hydrogen bromide with a predominance of the allene and 1,3-diene hydrobromides.

4. The hypothesis expressed previously of different mechanisms for the addition of halogens and hydrogen halides to vinylacetylene has been corroborated by new examples.

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INVESTIGATION OF CONJUGATED SYSTEMS

LXXVII. COMBINATION SCATTERING SPECTRA AND REACTIVITY OF VINYLACETYLENE HYDROCARBONS

A.A. Petrov, V.A. Kolesova and Yu. I. Porfiryeva

The possibility of using data on interatomic distances and infrared spectra for explaining specific rules on the reactivity of vinylacetylene hydrocarbons was investigated in one of the previous reports [1]. In continuing work on the development of the relationship between the physical properties and reactivity of vinylacetylene hydrocarbons, we investigated the combination scattering spectra of four examples of this class of substances; in this we were mostly interested in the polarizability of multiple bond systems.

The polarizability of a molecule as a whole and the magnitude of "conjugation" could be judged from molecular refraction and the magnitude of the exaltation. In Table 1 we compare the constants of vinylacetylene hydrocarbons of various structures and it shows that exaltation of molecular refraction does not appear in hydrocarbons with isolated multiple bonds. Vinylalkylacetylenes have the greatest exaltation value and isoalkenylacetylenes have the smallest, and here the exchange of a methyl for a tertiary butyl group results in a sharp decrease in exaltation. Alkenylacetylenes occupy an intermediate position.

The decrease in exaltation in the case of isoalkenylacetylenes is the usual effect of "central dislocation." The change in molecular refraction occurs here as a result of the sharp decrease in refractive index as compared with isomeric hydrocarbons. Usually vinylacetylenes have higher refractive indices than 1,3-dienes with the same number of carbon atoms. In this case it is less for isopropenylacetylene than for isoprene.

In a series of cases vinylacetylene hydrocarbons have lower values of molecular exaltation than the 1,3-dienes corresponding to them. Closest to dienes in the value of their exaltation are the vinylalkylacetylenes (EM_D : piperylene – 1.4 [3], 1-ethylbutadiene – 1.54 [4], isoprene – 1.06 [5], 2-tertiary butylbutadiene – 0.19 [6]).

One can conclude from this data that the greatest conjugation of multiple bonds occurs in vinylalkylacetylene molecules and that they would show a special tendency toward 1,4-addition. However, the reactions of vinylacetylene hydrocarbons do not confirm this conclusion.

In all the cases, hydrogen adds at the triple bond [7]. Hydrogen halides (without catalyst) add to vinylalkylacetylenes and isoalkenylacetylenes (isopropenylacetylene) in the 1,4-position to the acetylene bond and to alkenylacetylenes only at the acetylene bond [8]. In the presence of catalysts for allyl rearrangement, addition occurs almost exclusively at the triple bond, but not according to the hypothetical polarization of molecules under the effect of radicals [9]. A reverse picture is observed in relation to bromine: hydrocarbons of the first and second types add bromine mainly at the double bond [10] and alkenylacetylenes – at the 1,4-position [11]. Consequently, the most polarizable vinylalkylacetylenes and the least polarizable isoalkenylacetylenes behave qualitatively the same in relation to bromine (1,2-additon) and to hydrogen bromide (1,4-addition) and behave differently from alkenylacetylenes which occupy an intermediate position.

Thus, no definite conclusions on the reactivity of vinylacetylene hydrocarbons may be drawn from the data on molecular refraction.

In contrast to molecular refraction, combination scattering spectra make it possible to judge the polarizability of separate bonds.

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* Raman spectra.

Before this investigation, data on combination scattering spectra had been published in the literature for vinylacetylene [12-15], vinylmethylacetylene [16] (perylene, which, judging by the spectrum, was not a pure vinylmethylacetylene, as it contained a substance that is characterized by the frequencies 1618, 1936, 2189 cm^{-1}, which are not found in the spectrum of pure vinylmethylacetylene) and for some hydrocarbons with unconjugated bonds [17]. Selected data on the spectra of vinylmethyl- and vinylethylacetylenes are given in a paper written with the participation of the authors of this article [7].

In order to elucidate the basic rules in combination scattering spectra of vinylacetylene hydrocarbons, we investigated and analyzed the spectra of: vinyl-, vinylmethyl-, vinylethyl-, propenyl- and isopropenylacetylenes. Thus, we established that the basic rules, noted earlier in the spectra of ethylene, acetylene and 1,3-diene hydrocarbons, were also observed in this case.*

The group $-C\equiv CH$ is characterized first of all by the frequency 3300 cm^{-1} corresponding to CH valence oscillations, which is extremely intense in the infrared and weak in combination scattering spectra. The frequency $\omega_{C\equiv C}$ near 2100 cm^{-1}, which is very strong in combination scattering spectra and is of average intensity in infrared spectra, corresponds to the acetylene bond. The frequencies in the region 615-640 cm^{-1} correspond to the angular deformation oscillations $\delta_{C=C-H}$ and those in the region lower than 600 cm^{-1} correspond to $\delta_{C-C=C}$.

Oscillation of $\omega_{C\equiv C}$ in the $R-C\equiv C-R$ group are represented in the combination scattering spectra by an extremely intense frequency near 2230 cm^{-1} and a moderately intense frequency at 2330 cm^{-1}. The infrared spectra have one intense frequency near 2255 cm^{-1}. Besides these intense frequencies, both spectra have a series of lower frequencies, which are, possibly, composite ones.

The vinyl group was represented in both spectra by a characteristic frequency of CH valence oscillations in the $CH_2=$ group near 3100 cm^{-1} and in the $CH=$ group at $CH=$ – 3010–3040 cm^{-1}. The CH deformation oscillations were represented in both spectra by a frequency in the region of 1405–1415 cm^{-1}. Intense frequencies near 1600 cm^{-1}, lower than those of olefins, correspond to the valence oscillations $\omega_{C=C}$ in both spectra. The nonplanar deformation oscillations for the $CH_2=$ group are represented by frequencies near 920 cm^{-1} which are intense in the infrared and weak in the combination scattering spectrum. The infrared spectra also have one other extremely intense frequency near 970–980 cm^{-1} (for the $CH=$ group), while the combination scattering spectrum does not have this frequency.

The group $R_2C=CH_2$ is represented by the frequency 3100 (both spectra), 1621 (1612 in the infrared) and about 1430 cm^{-1} (near 1410 cm^{-1} – infrared). Nonplanar deformation frequencies of δ'_{CH} near 900 cm^{-1} have a high intensity in the infrared spectrum and a moderate one in the combination scattering spectra.

The group $CH=CH$ is represented by intense frequencies near 3020, 1616 (1623 in the infrared spectrum), 922 and a weak one at 948 cm^{-1}. An intense absorption band at 955 cm^{-1} in the infrared spectrum corresponds to the last frequency.

We will only make some remarks on the other frequencies.

The range of frequencies 2800–3000 cm^{-1} corresponds to CH valence oscillations. The frequency near 2865–2875 cm^{-1} is observed only in the infrared spectra of all the hydrocarbons and is, possibly, a composite one.

The range of frequencies 1550–1680 cm^{-1} corresponds to valence oscillations of the double bond. Besides the usual frequency of $\omega_{C=C}$ near 1600 cm^{-1}, almost all the hydrocarbons have another frequency near 1658 cm^{-1} in the infrared spectra; there are two frequencies in this range in the combination scattering spectra of propenylacetylene and of vinylalkylacetylenes which may possibly be connected with cis-transisomerism. It is difficult to explain the origin of the second frequency in the latter case, as in the case of the infrared spectra.

The range of frequencies 1050–1480 cm^{-1}, corresponds to CH deformation oscillations. The appearance of a CH_3 group in the molecule is accompanied by the appearance in the spectra of a frequency close to 1440 cm^{-1} and that of the CH_3-CH_2 group by a frequency near 1460 cm^{-1}. A quite intense frequency near 1270–1295 cm^{-1} is observed in both spectra of all the hydrocarbons.

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* The frequencies were assigned in accordance with the data found in Kohlrausch's book [18] and in more recent work [15].

Both of the vinylalkylacetylene spectra have an intense frequency near 1160 cm^{-1}, the other hydrocarbons have it only in the infrared spectra, while in the case of vinylacetylene it is absent in this spectrum as well. Alkenylacetylenes have a frequency of 1115 cm^{-1} in both spectra. This frequency is not observed in the spectra of the other hydrocarbons.

Frequencies which are assigned to valence oscillations of the hydrocarbon chain are also in this range (near 1220 – 1240 cm^{-1}).

The range of frequencies 900 – 1050 cm^{-1} corresponds to nonplanar CH deformation oscillations. Besides the characteristic frequencies examined earlier, all the hydrocarbons, with the exception of vinyl-acetylene, have in this range a frequency near 1020 – 1040 cm^{-1} in both spectra, which is more intense in the infrared spectra.

The range of frequencies 700– 900 cm^{-1} corresponds to oscillations of the carbon chain. The infrared spectra have more lines than the combination scattering spectra.

The range of frequencies 190 – 550 cm^{-1} corresponds to angular deformation oscillations $\delta_{C-C=C}$ and $\delta_{C-C\equiv C}$. We were unable to fully assign the frequencies in this range due to insufficient experimental data.

The position and intensity of multiple bonds were of greatest interest to us from the point of view of finding the relation between polarizability of bonds and reactivity. The data in Table 2 show that the value of the frequencies in the combination scattering spectra, as in infrared spectra, depends only on the position of these bonds in the chain and cannot be compared in any way with the rules on reactivity developed earlier.

The intensity of the bands in the combination scattering spectra corresponding to the acetylene bond is somewhat greater in all cases (by approximately 20%) than the intensity of the lines corresponding to the double bond. This indicates the greater polarizability of the triple bond in comparison with the double one and would be expected. The higher polarizability of the triple bond may, possibly, cause its high electrophilicity and, possibly, is the reason for the addition of hydrogen and hydrogen halide predominantly at the triple bond.

TABLE 1

Substance	boiling point	d_4^{20}	n_D^{20}	MR_D		
				found	calculated	
$CH_3-CH=CH-C\equiv CH$	46.5—47.5°	0.7293	1.4348	23.64	22.82	0.82
$C_2H_5-CH=CH-C\equiv CH$ . . .	72—74	0.7425	1.4381	28.34	27.44	0.90
$CH_2=C(CH_3)-C\equiv CH$	32—32.5	0.7064	1.4154	23.45	22.82	0.63
$CH_2=C[C(CH_3)_3]-C\equiv CH$ . . .	96.5—97.5	0.7584	1.4320	37.00	36.68	0.32
$CH_3-CH=C(CH_3)-C\equiv CH$ . .	65.5—66	0.7346	1.4302	28.19	27.44	0.75
$CH_2=CH-C\equiv C-CH_3$	59—59.5	0.7406	1.4488	23.93	22.82	1.11
$CH_2=CH-C\equiv C-C_2H_5$	83.5—84	0.7479	1.4522	28.92	27.44	1.47
$CH_2=CH-C\equiv C-C_3H_7$	108.5—109	0.7597	1.4529	33.49	32.06	1.43
$CH_2=CH-C\equiv C-C_4H_9$	133—135	0.7741	1.4555	37.95	36.68	1.27
$CH_2=CH-CH_2-C\equiv CH$	42—43	0.738 (16°)	1.4125 (16°)	22.31	22.82	—0.51 [2]
$CH_2=CH-CH_2-C\equiv C-CH_3$ . .	86—86.5	0.7630	1.4368	27.50	27.44	0.06 [7]

EXPERIMENTAL

The methods of preparing the hydrocarbons used in this work have been noted in previous reports. The constants of the hydrocarbons are given in Table 1. Propenylacetylene is a mixture of cis- and trans- forms with the former predominating [19].

The combination scattering spectra were plotted on an ISP-51 spectrograph. The spectra were excited with the mercury band at 4358 A. The violet part of the radiation was filtered with a saturated sodium nitrate solution. The exposure was 2.5 – 3 hours.

TABLE 2

$CH_2{=}CH{-}C{\equiv}CH$		$CH_3{-}CH{=}CH{-}C{\equiv}CH$		$CH_2{=}CCH_3{-}C{\equiv}CH$		$CH_2{=}CH{-}C{\equiv}C{-}CH_3$		$CH_2{=}CH{-}C{\equiv}C{-}C_2H_5$	
CSS	IRS	CSS	IRS	CSS	IRS	CSS	IRS	CSS	IRS
3305 (1)	**3300**	3300 (1)	**3300**	3300 (2)	**3300**	—	—	—	—
3102 (2)	3106	—	—	3103 (6)	**3106**	3101 (2)	**3115**	3110 (6)	3115
—	**[3067]**	3040 (1)	**3040**	3027 (4)	—	—	**[3058]**	3038 (8)	[3040]
3012 (4)	**3030**	3015 (2)	—	—	—	3014 (6)	**3030**	—	—
—	—	2979 (1)	**2985**	2982 (5)	**2994**	—	—	2983 (4)	**2976**
—	—	2949 (1d)	**[2941]**	2959 (1)	**2967**	—	**2941**	2948 (3)	**2933**
—	[2907]	2922 (7,	2915	2928 (8)	**2932**	2917 (12)	—	2923 (3)	[2907]
—	2865	—	2857	—	**[2874]**	—	**2857**	—	[2865]
—	—	—	—	2735 (1d)	—	—	—	—	—
—	**2304**	—	—	—	—	2336 (4)	—	2330 (4)	—
—	—	—	—	—	—	2235 (20)	**2257**	2230 (20)	2257
—	—	—	—	—	—	—	2208	2196 (4)	[2114]
2099 (6)	2114	2100 (15)	**2114**	2100 (15)'	2114	2094 (1)	2075	2098 (1d)	—
—	—	—	—	2025 (1)	—	—	—	—	—
—	1658	1630 (8)	1661	1656 (1)	—	—	1655	—	1658
1595 (5)	**1610**	1616 (10)	1623	1612 (12)	**1623**	1606 (15)	**1608**	1606 (15)	**1608**
—	—	—	—	—	—	1589 (2)	—	1592 (3)	—
—	—	—	—	—	—	—	—	1460 (1)	**1468**
—	—	1441 (8)	**1445**	1444 (4)	**1451**	—	**1445**	1435 (1)	**[1445]**
1405 (4)	**1412**	—	—	1429 (1)	1412	1409 (8)	**1418**	1414 (12)	[1422]
—	—	1391 (2)	**[1383]**	1387 (10)	—	—	—	1391 (4)	—
—	—	1373 (2)	—	1372 (2)	**1379**	1377 (6)	**[1379]**	1377 (2)	1381
—	1357	1360 (1)	**1354**	—	—	—	—	—	—
—	—	1301 (6)	—	—	—	—	—	—	1323
1288 (4)	—	1279 (1)	**[1280]**	1284 (0)	**1272**	1291 (10)	1295	1291 (10)	**[1295]**
—	**1241**	1227 (8)	**1221**	1264 (4)	**1230**	—	—	—	—
—	—	—	**[1151]**	—	1174	1166 (6)	**1167**	1166 (5)	**1167**
—	—	1115 (1)	**1119**	—	—	—	—	—	—
1091 (2)	**1096**	—	1075	—	[1096]	—	[1069]	1067 (3)	1071

Note: d = diffuse

TABLE 2 (Cont'd.)

CH_2=CH–C≡CH		CH_3–CH=CH–C≡CH		CH_2=CCH$_3$–C≡CH		CH_2=CH–C≡C–CH$_3$		CH_2=CH–C≡C–C$_2$H$_5$	
CSS	IRS	CSS	IRS	CSS	IRS	CSS	IRS	CSS	IRS
—	—	1028 (7)	**1028**	1010 (5)	**1015**	1032 (3d)	**1029**	1038 (5)	1038
—	**971**	—	—	983 (1)	—	—	**976**	—	**980**
—	—	948 (1)	**955**	952 (5)	(960)	—	—	942 (5)	—
928 (2)	**929**	922 (7)	—	902 (5d)	**903**	918 (3d)	**920**	917 (2)	**919**
875 (2)	879	—	843	—	**837**	—	(870)	—	—
—	—	782 (5)	—	—	782	—	—	780 (2)	780
—	—	—	—	763 (9)	762	746 (0d)	745	—	—
—	—	—	**729**	718 (1b)	720	702 (1)	701	—	—
678 (2)	676	—	—	—	—	677 (3)	676	681 (5)	—
—	—	—	—	—	—	657 (1)	—	—	—
629 (4b)	—	637 (2d)	—	615—640 (6, band)	—	—	—	—	
538 (4)	—	—		545 (1)		—		—	
—		—		524 (8)		521 (7)		—	
—		490 (7)		—		—		486 (1d)	
—		—		—		—		473 (1d)	
—		385 (1)		391 (9)		376 (1d)		—	
—		367 (2)		—		363 (4d)		359 (4d)	
309 (4в)		330 (1)		—		317 (6d)		334 (1,	
219 (4 b)		267 (1d)		260 (6)		—		220 (3bd)	
--		171 (10b)		190 (10b)		—		—	

Note. CSS - Combination scattering spectrum, IRS - infrared spectrum, d - diffuse, b – broad.

*Transliterated as v – a Russian symbol in Raman spectra unknown to publisher – Publisher's note

The data obtained are given in Table 2; the infrared spectra are also given there.*

Table 2 does not include frequencies in the ranges 2300–2800 and 1700–2000 cm^{-1}, found only in the infrared spectra and, apparently, overtones of the main frequencies.

SUMMARY

1. The combination scattering spectra of four vinylacetylenes were investigated.

2. It was shown that the basic rules, established earlier for olefin and acetylene spectra, were observe in these spectra.

3. It was established that the value of the multiple bond frequencies was determined by the position of the bonds in the chain. The intensity of the frequencies corresponding to the triple bond was greater in all cases than that of the double bond. This indicates the higher polarizability of the triple bond.

4. We put forward the hypothesis that the higher reactivity of the triple bond in relation to hydrogen and hydrogen halide is due to its high polarizability.

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* The infrared frequencies of high intensity have been emphasized. The frequencies appearing in the infrared spectra as projections on more intense absorption bands are in square brackets.

** Original Russian pagination. See C. B. translation.

*** Russian translation.

INVESTIGATIONS IN THE FIELD OF POLYMETHYLENE RINGS

XXVIII. INVESTIGATION OF THE REACTION PRODUCTS OF OF ACETONYLACETONE WITH HYDRAZINE

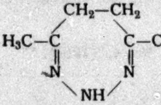
N.A. Domnin, M.N. Zelenina and N.S. Glebovskaya

We previously investigated the reaction of acetonylacetone with hydrazine in another connection [1]. We then assumed, without sufficient proof, that the main product of this reaction was 2-amino-3,6-dimethyldihydropyridazine. In studying this reaction further and more thoroughly, we obtained very interesting new data and this report is devoted to them.

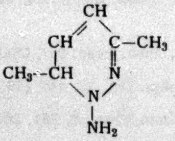
Gray studied the reaction of 1 acetonylacetone molecule with 2 molecules of hydrazine hydrate [2]. He obtained a product with a compositon of $C_{12}H_{24}N_6$. Without giving data on the determination of molecular weight and without giving any proof of the structure of the product obtained, Gray arbitrarily concluded that in this reaction 2 acetonylacetone molecules combined with 3 hydrazine hydrate molecules and ascribed an unsubstantiated structural formula to the substance obtained. Zimmerman later repeated the reaction of acetonylacetone with excess hydrazine [3]. He isolated a substance that had identical physical constants to Gray's substance and accepted, without proof, that this was Gray's azinehydrazone.

As these papers did not give any proof of the structure of the product obtained, we studied the reaction of acetonylacetone with hydrazine more thoroughly. The data we obtained on the determination of molecular weight and from elementary analysis indicate that the reaction product has a composition of $C_6H_{11}N_3$.

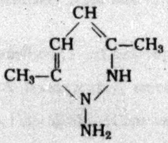
The following possible structural formulas correspond to this molecular composition:



(I)



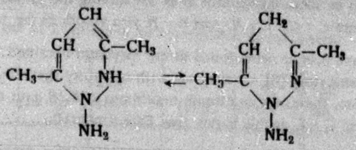
(II)



(III)

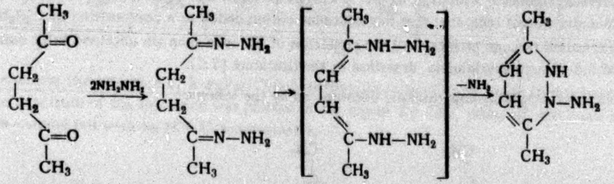
The compound obtained gave a characteristic condensation product with phthalic anhydride that proved the presence of a primary amino group in it. Formula (I) was eliminated on the basis of this reaction and formulas (II) and (III) remained. The substance investigated reacted with benzoyl chloride – a characteristic reagent for primary and secondary amines – to give the product of adding two molecules of benzoyl chloride. This reaction eliminated formula (II) and formula (III) can be accepted for the substance. It should be noted that in reacting acetonylacetone with hydrazine under the same conditions, we obtained compounds with the same composition but with different melting points. The melting point changed both on recrystallization and on standing.

A probable explanation for this phenomenon seemed to us to be the presence here of imino-eneamino tautomerism.



Probably, the most stable tautomeric form here would be 2-amino-3,6-dimethyldihydropyridazine with a conjugated system of double bonds.

The formation of 2-amino-3,6-dimethyldihydropyridazine-1,2 may be expressed by the following scheme



We assumed that a tautomeric dihydrazone molecule was formed as an intermediate product (shown in square brackets in the scheme), which lost ammonia and closed to give a six-membered ring.

We used infrared spectroscopy to confirm the structure of the substance investigated. The absorption spectrum of the substance was studied from 2 to 15 μ. The literature data on the infrared spectra of amines, hydrazine and unsubstituted and substituted amides indicate that the absorption maxima corresponding to valence oscillations of the N-H bond lie in the region of 3 μ and those of the deformation oscillations of NH_2 – 6 μ [4,5].

TABLE 1

Benzene absorption maxima (in cm^{-1})	Characteristics of benzene absorption maxima	Pyrimidine absorption maxima (in cm^{-1})	Characteristics of pyrimidine absorption maxima	Absorption maxima of 3,6-dimethylpyridazine-1,2.
849	Oscillations C—H [9]	825	Oscillations C—H [10]	835
1033	—	1000	Deformation oscillations C—H [11]	1035
1150	—	1140	Deformation oscillations C—H [11]	—
1175	—	1165	Deformation oscillations C—H [11]	1170
1247	—	1230	Deformation oscillations C—H [11]	1260
1478	—	1465		1445
1530	Oscillations characteristic of aromatic system bonds [9]	1570	Oscillations characteristic of aromatic system bonds [9]	1550
1588		1610		1590
1650		1650		1659
3065	Oscillations C—H [9]	—		—
—	—	3400	Oscillations C—H [11]	3402

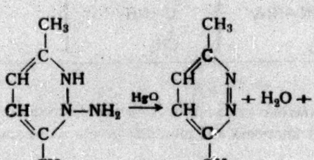
The region of 3 μ appeared to be more convenient to us for solving the problem of the presence of an NH_2 group in the compound, as the groups C = C, C = N and N = N also absorb in the region of 6 μ.

Absorption maxima at 3.03 and 3.11 μ were found in the spectrum obtained. Guided by the literature data and work, carried out in our laboratory [6], we may say with certainty that these absorption maxima correspond to the NH_2 group. Furthermore, there was an intense maximum at 6.16 μ in the absorption spectrum, which characterizes a conjugated system of C = C double bonds (see Experimental).

We thus consider it proved that as a result of reacting 1 acetonylacetone molecule with 2 hydrazine hydrate molecules, 2-amino-3,6-dimethyldihydropyridazine is formed.

2-Amino-3,6-dimethyldihydropyridazine was subjected to oxidative, alkali-catalyzed decomposition, which proceeded with nitrogen evolution, but the final product was a high boiling, nitrogen-containing compound. The formation of the final product was unaffected by variations in the reaction conditions (heating time, presence of catalyst). An individual substance with m.p. 31-32° was isolated from the high boiling fraction. Elementary analysis and molecular weight indicated that this substance corresponded to a composition of $C_6H_8N_2$. The substance was characterised through picrate. All the properties of the substance we obtained fully coincided with the properties of 3,6-dimethylpyridazine, described in the literature [7,8].

2-Amino-3,6-dimethyldihydropyridazine decomposed by the scheme



The formation of 3,6-dimethylpyridazine confirmed the accuracy of the structure we had established for the reaction product of acetonylacetone with hydrazine, that of 2-amino-3,6-dimethyldihydropyridazine-1,2.

The literature indicates that the absorption spectra in the infrared region for aromatic heterocyclic compounds – pyridine, pyrimidine and their derivatives – have been quite thoroughly studied [9,10]. It was shown that there is much similarity between the absorption spectra of benzene and aromatic heterocylic compounds. A thorough study of the absorption spectrum of 3,6-dimethylpyridazine seemed to be interesting in itself. We plotted the region of 2 – 13 μ using an NaCl prism. In processing the results, we found that all the maxima, characteristic of benzene, pyridine and pyrimidine were in the spectrum of 3,6-dimethylpyridazine.

We give in Table 1 the maxima characteristic of benzene, pyrimidine and 3,6-dimethylpyridazine.

EXPERIMENTAL

We have already described [1] the synthesis and general characteristics of the reaction product from acetonylacetone and hydrazine hydrate, 2-amino-3,6-dimethyldihydropyridazine. Here we present new data as proof of its structure and also the results of oxidative decomposition of 2-amino-3,6-dimethyldihydropyridazine.

The condensation product of 2-amino-3,6-dimethyldihydropyridazine and phthalic anhydride was prepared by Johnson's method [12]. It formed white, needlelike crystals. The m.p. was 308 – 310°.

Found %: N 16.52, 16.56. $C_{14}H_{13}O_2N_3$.
Calculated %: N 16.47.

The condensation product of 2-amino-3,6-dimethyldihydropyridazine and benzoyl chloride was prepared by Buttschneicher's method [13]. The condensate was recrystallized from alcohol and benzene. The m.p. was 236 – 237°.

Found %: N 12.45, 12.20. $C_{20}H_{19}O_2N_3$.
Calculated %: N 12.61.

TABLE 2

Absorption Maxima of 2-amino-3,6-dimethyldihydropyridazine

Test No.	λ (in μ)	ν (in cm^{-1})	Test No.	λ (in μ)	ν (in cm^{-1})	Test No.	λ (in μ)	ν (in cm^{-1})
1	3.03	3300	10	7.90	1266	19	10.52	951
2	3.11	3223	11	8.06	1241	20	10.74	931
3	5.34	1873	12	8.32	1201	21	11.43	873
4	6.16	1624	13	8.68	1152	22	12.83	780
5	6.83	1465	14	8.90	1124	23	13.15	761
6	6.89	1450	15	9.26	1079	24	13.58	737
7	7.00	1429	16	9.82	1018	25	13.93	718
8	7.10	1409	17	9.89	1012	26	14.62	684
9	7.39	1354	18	10.14	986			

Spectroscopic investigation of 2-amino-3,6-dimethyldihydropyridazine in the infrared region (Table 2, Fig. 1). The spectrum of the substance was plotted in the region 2 – 15 μ using LiF and NaCl prisms, in vaseline oil. This was carried out with an IKS-11 spectrometer.

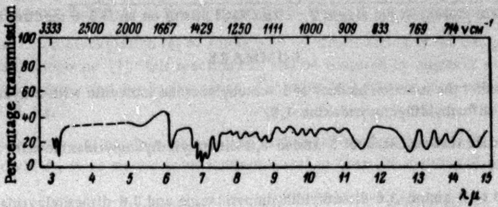


Fig. 1. Transmission curve of 2-amino-3,6-dimethyl-hydropyridazine.

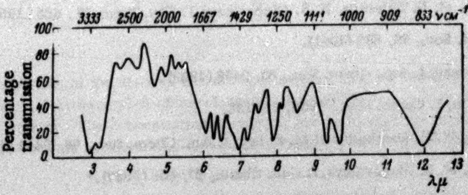


Fig. 2. Transmission curve of 3,6-dimethylpyridazine.

Preparation of 3,6-dimethylpyridazine. 156 g of yellow mercury oxide and 100 ml of anhydrous alcohol were placed in a round-bottomed flask with a reflux condenser, a dropping funnel and a mechanical stirrer. A solution of 45 g of 2-amino-3,6-dimethyldihydropyridazine in 100 ml of alcohol was introduced into the flask dropwise. The reaction mixture was heated on a water bath for 5 hours. During the reaction, nitrogen was evolved. Heating was stopped when the evolution of nitrogen ceased. After cooling the solution, the mercury was filtered off and the alcohol distilled off. The residue was distilled in vacuum. The main fraction was collected at 100 – 102° (15 mm) and crystallized in the condenser. We obtained 5 g of a substance with m.p. 31 – 32°. The addition of a saturated alcohol solution of KOH did not accelerate the reaction.

Found %: C 66.26, 66.65; H 7.51, 7.61; N 25.85, 25.77. M 111, 108. $C_6H_8N_2$.
Calculated %: C 66.52, H 7.55; N 25.88. M 108.

We prepared a picrate with m.p. 163.5°.

Found %: N 20.82, 20.93. $C_{12}H_{11}O_7N_5$.
Calculated %: N 20.77.

TABLE 3
Absorption Maxima of 3,6-dimethylpyridazine

Test No.	λ (in μ)	ν (in cm^{-1})	Test No.	λ (in μ)	ν (in cm^{-1})	Test No.	λ (in μ)	ν (in cm^{-1})
1	2.94	3402	8	5.42	1845	15	7.94	1260
2	3.27	3059	9	6.03	1659	16	8.17	1224
3	3.77	2653	10	6.29	1590	17	8.61	1161
4	4.29	2326	11	6.44	1552	18	9.29	1076
5	4.66	2146	12	6.96	1436	19	9.66	1035
6	5.05	1980	13	7.28	1374	20	11.98	835
7	5.30	1887	14	7.56	1323			

Spectroscopic investigation of 3,6-dimethylpyridazine in the infrared region (Table 3, Fig. 2). The spectrum of the substance was plotted in the region 2 – 13 μ (NaCl prism) on an IKS-6 spectrometer.

SUMMARY

1. It was proved that the reaction product of 1 acetonylacetone molecule with 2 hydrazine hydrate molecules is 2-amino-3,6-dimethyldihydropyridazine-1,2.

2. It was established that oxidation of 2-amino-3,6-dimethyldihydropyridazine with mercuric oxide gave 3,6-dimethylpyridazine.

3. The structures of 2-amino-3,6-dimethyldihydropyridazine and 3,6-dimethylpyridazine were confirmed by absorption spectra in the infrared region.

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*Original Russian pagination. See C. B. translation.

ISOMERIZATION OF α-HYDROXYALDEHYDES

XIV. SYNTHESIS OF GLYCERALDEHYDE DERIVATIVES

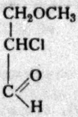
S.N. Danilov and V.I. Ivashchenko

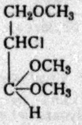
For many examples of monohydroxy- and monohalo-aldehydes, the hydroxyketonic and acid conversions have been studied (S. N. Danilov, E. D. Venus-Danilova et al [1,2]). The little information [3] that exists on the hydroxyketonic conversion of glyceraldehyde (dimer) and its derivatives should be extended.

For the preparation of derivatives of this hydroxyaldehyde, which is frequently prepared by Wohl's method [4], we used the chloroalkoxylation and chloroacetoxylation of acrolein. When the main outline of our work had been completed, a report appeared on the synthesis of glyceraldehyde itself from acrolein by the addition of hypochlorous acid with subsequent hydrolysis of the ethylene glycol acetal of α-chloroglyceraldehyde [5].

We achieved the chloroalkoxylation [6] of acrolein by the direct action of the halogen on an alcohol solution of the unsaturated compound [7]; this reaction can also be achieved by means of acid chloramides [6,8]. The chloroacetoxylation was carried out by the action of chlorine on a solution of acrolein (as the diacetyl derivative) in acetic acid [8, 9].

In the chloroalkoxylation of acrolein we obtained 2-chloro-3-methoxypropanal (I), 2-chloro-3-methylglyceraldehyde or its acetal (II), if we started from acrolein acetal or when the reaction of the alcohol solution became acid.


(I)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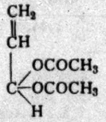
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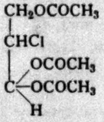
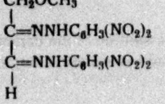

(IV)

In the chloroacetoxylation of the diacetyl derivative of acrolein (III) we obtained 2-chloro-1,1,3-triacetyl-propanal (IV), otherwise , 1,1-diacetyl-2-chloro-3-acetyl-glyceraldehyde. In both cases the corresponding dichloro derivatives were present. The concentration of chlorine had to be kept low during the synthesis. The presence of free hydrogen chloride increased the amount of dichlorides, and to avoid this, sodium acetate was added [10].

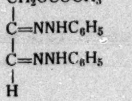
The structures of the chloromethoxyl and chloroacetoxyl compounds were readily proved by preparing osazones owing to hydrolysis of the chloro derivative with the substitution of hydroxyl for halogen.

In the case of 2-chloromethoxyglyceraldehyde (I), an osazone was formed by treatment with 2,4-dinitrophenylhydrazine in sulfuric acid (V). An osazone was not obtained with phenylhydrazine in aqueous acetic acid. The osazones (VI) and (VII), for acetylglyceraldehyde chlorohydrin (IV), were synthesized by using both of the hydrazine derivatives mentioned.



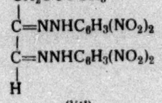
$$\begin{array}{l} CH_2OCH_3 \\ | \\ C{=}NNHC_6H_3(NO_2)_2 \\ | \\ C{=}NNHC_6H_3(NO_2)_2 \\ | \\ H \end{array}$$

(V)



$$\begin{array}{l} CH_2OCOCH_3 \\ | \\ C{=}NNHC_6H_5 \\ | \\ C{=}NNHC_6H_5 \\ | \\ H \end{array}$$

(VI)



$$\begin{array}{l} CH_2OCOCH_3 \\ | \\ C{=}NNHC_6H_3(NO_2)_2 \\ | \\ C{=}NNHC_6H_3(NO_2)_2 \\ | \\ H \end{array}$$

(VII)

In this article, we confine ourselves to the synthesis of substituted derivatives of glyceraldehyde.

EXPERIMENTAL

1. Chloroacetoxylation of Acrolein

Acrolein, prepared by the usual method [11], was stored in a dark container with an inhibitor (hydroquinone, pyrogallol) to prevent polymerization; b.p. 52 – 52.5°, d^{20}_{20} 0.840, n^{20}_{D} 1.3998.

The diacetyl derivative of acrolein (III) was prepared by a slight variation of the well-known method [12]. A mixture of acrolein and acetic anhydride (1:1) was heated in the container of an enamelled calorimetric bomb (instead of a glass tube) in the presence of cuprous chloride as an inhibitor (3% of the weight of the acrolein) for 6 – 7 hours at about 100° (bomb in boiling water). The reaction mixture was then distilled in vacuum and not poured into water as recommended in the literature.

The acrolein diacetate (III) dissolved readily in alcohol and acetone, but was insoluble in water.

B.p. 72-74° (12 mm), d^{20}_{20} 1.0720, n^{20}_{D} 1.4215, MR_D 37.41; calc. 37.37.

For the synthesis of 2-chloro-1,1,3-triacetylglyceraldehyde, 50 g of acrolein diacetate, glacial acetic acid (6 moles of acetic acid to 1 mole of diacetate) and sodium acetate (40 – 50 g) to combine with the hydrogen chloride were placed in a three-necked flask, fitted with a reflux condenser, a stirrer and a tube for passing chlorine. Chlorine was passed in a slow stream at a rate of 2 – 3 bubbles per second. The temperature of the reaction mixture was 6 – 9° and the reaction time 6 – 7 hours. A precipitate of sodium chloride formed.

The reaction product was separated by two methods:

a) an ether extract was washed with water to remove sodium acetate, dried with sodium sulfate and after distilling off the ether, the substance was distilled in vacuum;

b) after separating the sodium chloride, it was more convenient to distil off the acetic acid in vacuum, which precipitated the sodium acetate, to extract with ether and distil the product in vacuum at 1 – 2 mm.

After several distillations (fractions checked by chlorine content and physical properties) we obtained the material in a pure form in 40% yield from the higher boiling fraction.

B.p. 123–124° (1.5 mm), d^{20}_{20} 1.2552, n^{20}_{D} 1.4420, MR_D 53.25; calc. 53.59
Found %: Cl 14.26, 14.31. $C_9H_{13}O_6Cl$.
Calculated: %: Cl 14.06.

This substance was accepted as 2-chloro-1,1,3-triacetylglyceraldehyde (IV). It reacted with Fehling's solution and an ammonia solution of silver oxide; it was soluble in organic liquids but not in water.

A lower boiling substance with a high chlorine content (30.8%) corresponded to dichloroacrolein diacetate, which we did not investigate.

We prepared the phenylosazone (VI) and the 2,4-dinitrophenylosazone (VII) from the acetylglyceraldehyde. To an alcohol solution of 2-chloro-1,1,3-triacetylglyceraldehyde diacetate was added an alcohol solution of phenylhydrazine hydrochloride and sodium acetate (1 part of aldehyde, 2 parts of phenylhydrazine hydrochloride and 3 parts of sodium acetate), the solution was heated on a boiling water bath for 5-10 minutes and, after cooling it was slowly poured into vigorously stirred ice water. The flocculent precipitate was filtered off, washed with cold water and alcohol and dried in a desiccator over calcium chloride. On prolonged storing, the precipitate became brown. The m.p. was 82° (determined by Fisher's method for osazones with a heating rate of 14-16° per minute). A Beilstein test for halogen was negative.

The substance was the phenylosazone of acetylglyceraldehyde (VI).

Found % : N 18.20, 17.99 (Dumas). $C_{17}H_{18}O_2N_4$.
Calculated %: N 18.06.

We also prepared the 2,4 dinitrophenylosazone. To an alcohol solution of the carbonyl compound was added a solution of 2,4-dinitrophenylhydrazine in a mixture of alcohol and sulfuric acid, allowing 0.4 g of hydrazine derivative to 0.5 g of the carbonyl compound. The solution was heated on a boiling water bath for 10 minutes, which gave a voluminous reddish precipitate. After washing with alcohol and drying in a desiccator, the osazone had m.p. 278° (under Fischer's conditions).

Found %: N 23.19, 23.16. $C_{17}H_{14}O_{10}N_8$.
Calculated %: N 22.80.

Analysis confirmed that the substance was the 2,4-dinitrophenylosazone of acetylglyceraldehyde (VII).

We carried out experiments on the substitution of chlorine by an acetyl group in 2-chloro-3-acetylglyceraldehyde diacetate by heating with potassium acetate in acetic acid (6, 15, 30 and 100 hours). However, even after 100 hours heating, the chlorine was not completely hydrolyzed and the amount of potassium chloride liberated was only 40% of theoretical so that we were able to recover 55 – 60% of the starting material. On heating the chloroacetate with silver nitrate, silver chloride was formed.

2. Chloromethoxylation of Acrolein*

In the same apparatus as described for the chloroacetoxylation of acrolein, a mixture of acrolein and 6 – 8 times the amount of methyl alcohol with 1% hydroquinone and excess chalk, was treated with chlorine which was passed at a rate of 2 – 3 bubbles per second at normal temperature, while the mixture was stirred vigorously. When the chlorine was passed rapidly, the dichloroacerolein content was increased and the solution darkened. As the reaction proceeded, chalk was gradually added so that the reaction did not become acid. The reaction proceeded, at 5 – 10° and was followed by the disappearance of double bonds (bromination). In an acid medium, acrolein acetal was formed. The substance was distilled off with steam, then extracted with ether and dried with sodium sulfate. We obtained a mixture of three or four products: 2-chloro-3-methoxyglyceraldehyde, dichloroacrolein and their methyl acetals, which had to be distilled carefully. Therefore, before the distillation, the acetal (II) present was hydrolyzed by heating to 50 – 60° with 5% sulfuric acid for 3 –5 hours and then we removed the sulfuric acid with barium carbonate and extracted the substance with ether.

On heating the mixture in a stream of carbon dioxide, we isolated 2-chloro-3-methoxyglyceraldehyde (I) (about 25% yield).

B.p. 83.5–84° (18 mm), d_{20}^{20} 1.1851, n_D^{20} 1.4420, MR_D 27.34, calc. 27.19.
Found %: Cl 28.68. $C_4H_7O_2Cl$.
Calculated %: Cl 28.94.

2-Chloro-3-methoxyglyceraldehyde had a slight, characteristic smell, on heating it reduced Fehling's solution and was readily soluble in alcohol, ether and acetone and insoluble in water.

Due to the effect of the methoxyl group, the chlorine atom was not hydrolyzed on heating with silver nitrate in aqueous and alcohol solution and substitution of the chlorine did not occur on heating with potassium acetate in acetic acid on a water bath. The phenylosazone was not prepared, but it was possible to synthesize the 2,4-dinitrophenylosazone. Apparently, the concentrated sulfuric acid promoted the hydrolysis of the chlorine on the second carbon atom. The 2,4-dinitrophenylosazone of 3-methoxyglyceraldehyde (V) obtained had m.p. 282°.

Found %: N 24.43, 24.38. $C_{16}O_{16}O_9N_8$.
Calculated %: N 24.17.

SUMMARY

1. We describe 2-chloro-1,1,3-triacetylpropanal, which was prepared from acrolein diacetate, its phenylosazone and 2,4-dinitrophenylosazone.

2. By chloroalkoxylation of acrolein we obtained 2-chloro-3-methoxypropanal, which was characterized as the 2,4-dinitrophenylosazone.

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* With the participation of R. T. Vorobeva.

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STUDY OF THE PROCESS OF DEACETYLATION OF ACETYLCELLULOSE

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In recent years in the literature, mainly foreign literature, there has appeared a series of papers [1 – 4], devoted to studying the mechanism of acetylation and hydrolysis of incompletely acetylated (so-called secondary) acetylcellulose in order to elucidate the relation between the reaction conditions and the relative reactivities of the primary and secondary hydroxyl groups in the cellulose macromolecule.

Hiller [1] established that in the treatment of secondary cellulose acetate with acetic acid and water, two reverse processes (hydrolysis of the acetate groups and their reacetylation) occurred at the same time and that the rate and equilibrium constants of these processes were different and were determined by the nature of the hydroxyl groups. The introduction of a catalyst did not affect the final result of the processes, but accelerated them. Malm et al. [2,3] showed that in the treatment of secondary cellulose acetate with mixtures of various solvents with water, the nature of the hydroxyls in the hydrolyzed product was determined not only by the water content of the mixture, but also by the possibility of reesterification of the primary hydroxyls.

The aim of the present work was the study of the kinetics of deacetylation of acetylcellulose by the reagents most commonly used in practice and the nature of the hydroxyl groups hydrolyzed under these conditions.

EXPERIMENTAL

As the starting material we used secondary acetylcellulose, prepared under industrial conditions and additionally purified by precipitation from acetone solution with water, which contained 58.8% acetyl groups (degree of substitution 2.78). As hydrolyzing agents we used pyridine, 99.8% acetic acid, 80% acetic acid and 95% acetic acid with 2% catalyst – H_2SO_4. The hydrolysis was carried out homogeneously at 20°. The concentration of acetylcellulose in solution was 10% in the case of pyridine and 5% in all the other cases.

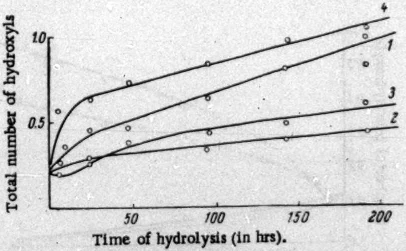

Fig. 1. Relation of the change in the total number of free hydroxyls to the time of hydrolysis.
1) Pyridine, 2) glacial acetic acid, 3) 95% acetic acid + + 2% H_2SO_4, 4) 80% acetic acid.

For the hydrolysis in the presence of acetic acid, the acetylcellulose was first dissolved in 99.8% acetic acid and then the calculated amount of water or mixture of water and sulfuric acid was added to the solution in small portions with careful stirring.

Samples were taken after 6, 24, 48, 96, 144 and 192 hours and after appropriate treatment, we determined the amount of acetyl groups and the free primary hydroxyl group content in them. In all the samples investigated, we analyzed for acetate group content by alkaline hydrolysis, using 0.5 N aqueous NaOH as the hydrolyzing agent. A sample of the acetylcellulose was first dissolved in pyridine so that the hydrolysis could be carried out homogeneously.

The data given in Fig. 1 show that the strongest hydrolyzing effect is shown by 80% acetic acid and pyridine and that during the hydrolysis with 95% acetic acid in the presence of H_2SO_4 catalyst, in the first stage there is a slight increase in the content of ester groups, apparently, due to the formation of cellulose sulfoesters, which were then hydrolyzed.

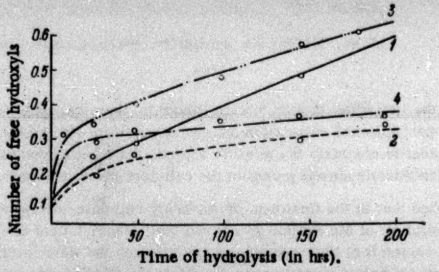

Fig. 2. Relation of the change in the amount of free primary and secondary hydroxyls to time of hydrolysis in pyridine and in 80% acetic acid.
1) primary hydroxyls (in pyridine), 2) secondary hydroxyls (in pyridine), 3) primary hydroxyls (in 80% acetic acid), 4) secondary hydroxyls (in 80% acetic acid).

Since it was shown that in the treatment of acetylcellulose with pyridine, acetate groups were hydrolyzed, then in order to clarify the question of the accuracy of determining primary hydroxyl groups in partially hydrolyzed acetylcellulose by tosylation – iodination (which is carried out homogeneously in pyridine, a solvent both for acetylcellulose and for tosyl chloride), we determined the number of acetate groups in acetylcellulose before and after its tosylation. We established that during tosylation under the usual conditions (see below), hydrolysis

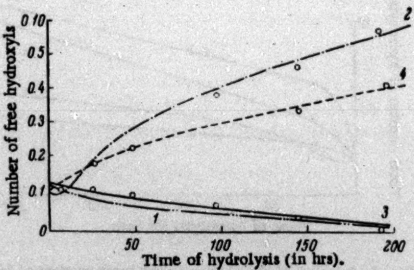

Fig. 3. Relation of the change in the amount of free primary and secondary hydroxyls to time of hydrolysis in glacial acetic acid and in 95% acetic acid with catalyst.
1) Primary hydroxyls (95% acetic acid + 2% H_2SO_4), 2) secondary hydroxyls (95% acetic acid + 2% H_2SO_4), 3) primary hydroxyls (glacial acetic acid), 4) secondary hydroxyls (glacial acetic acid).

of the acetate groups practically did not occur. In the sample investigated, the degree of substitution by acetate groups was 2.73 before tosylation and 2.72 after tosylation. Apparently, the presence of a considerable amount of tosyl chloride in the solution slowed down the process of hydrolysis of acetylcellulose by pyridine.

The nature of the free hydroxyl groups was determined by tosylation – iodination [5, 6]. The tosylation was carried out with a ratio of 8 moles of tosyl chloride and 15 moles of pyridine to 1 mole of acetylcellulose for 3 days at 20°. The iodination proceeded by the action of NaI in methyl isobutyl ketone at 110° for 4.5 hours. The S and I contents were determined by the Carius method.

The results of the determinations are given in Figs. 2 and 3, which show that on treating acetylcellulose both with pyridine and 80% acetic acid, the initial rates of hydrolysis of acetate groups, substituting both primary and secondary hydroxyls, are close to each other. On hydrolyzing for a longer time, the increase in the total number of free hydroxyl groups is mainly due in this case to an increase in the number of free primary hydroxyl groups. On treating acetylcellulose with 99.8 and 95% acetic acid in the presence of catalyst, in addition to the growth in the total number of free hydroxyl groups, there is a decrease in the amount of free primary hydroxyls and an increase in the free secondary hydroxyls, apparently due to the lower rate of re-esterification of the latter.

SUMMARY

By using as hydrolyzing agents pyridine, 99.8 and 80% acetic acid and 95% acetic acid with 2% H_2SO_4, it is possible to direct the deacetylation of acetylcellulose so as to obtain a product containing primary and secondary hydroxyl groups in the required ratio.

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THE REACTION OF TRITHIANES WITH SULFENYL CHLORIDES

K.A. Petrov and G.A. Sokolsky

It is known that the symmetrical trithianes (trimers of thioaldehydes and thioketones) are able to undergo chemical reactions, accompanied by cleavage of the trithiane ring. Thus, on reacting sulfur chlorides with tri-thioformaldehyde and trithioacetaldehyde, α, α'-dichlorodimethyl sulfide and α,α'-dichlorodiethyl sulfide were obtained [1]. The reaction of chlorine with trithiane at low temperature gave chloromethylsulfenyl chloride [2] and at room temperature, dichloromethylsulfenyl chloride [3]. Alkyl substituted trithianes are cleaved by chlorine to form α-chloroalkylsulfenyl chlorides [4]. From the data given we would expect that trithianes would be cleaved by sulfenyl chlorides to form unsymmetrical α-chloroalkyl sulfides. The present work is devoted to the study of this reaction.

The reaction of alkylsulfenyl chlorides with trithianes was studied using as examples ethyl-, β-chloroethyl- and benzylsulfenyl chlorides and trithioformaldehyde. On performing the reaction without solvent, there was a strong evolution of heat, violent evolution of hydrogen chloride and the formation of black-brown tarry products, from which individual substances could not be isolated. Only by performing the reaction in carbon tetrachloride solution, were we able to obtain the corresponding α-chloroalkyl sulfides. Ethyl, β-chloroethyl and benzyl chloromethyl sulfides were prepared by this method.

$$(CH_2S)_3 + 3R{-}S{-}Cl \longrightarrow 3R{-}S{-}CH_2Cl + 3S$$

EXPERIMENTAL

Reaction of sulfenyl chlorides with trithioformaldehyde. A solution of ethyl-, β-chloroethyl- or benzylsulfenyl chloride in five times the volume of anhydrous carbon tetrachloride was slowly added to the calculated amount of powdered trithioformaldehyde. We observed the evolution of heat, frothing and the gradual solution of the trithioformaldehyde. After 30 minutes standing, the reaction mixture was heated at 50 – 60° for 1 hour. After cooling, the undissolved residue was filtered off and the solvent distilled off. The residue was twice fractionated in vacuum. We isolated the following substances.

Ethyl chloromethyl sulfide, yield 37% B.p. 51–53° (17 mm), d_4^{20} 1.3734, n_D^{20} 1.5276.

Found %: Cl 32.37. C_3H_7ClS.
Calculated %: Cl 32.13.

Literature data [5]: b.p. 50–51° (16 mm), d_4^{20} 1.3710, n_D^{20} 1.5284.

β-Chloroethyl chloromethyl sulfide, yield 49%. B.p. 74–76° (12 mm), d_4^{20} 1.3300, n_D^{20} 1.5281.

Found %: Cl 48.62; S 22.34. $C_3H_6Cl_2S$.
Calculated %: Cl 48.97; S 22.07.

Literature data [5]: b.p. 79–80° (15 mm), d_4^{20} 1.3310, n_D^{20} 1.5280.

Benzyl chloromethyl sulfide, yield 75.5%. B.p. 105–106° (6 mm), d_4^{20} 1.1915, n_D^{20} 1.5857.

Found % Cl 20.90; S 18.32. C_8H_9ClS.
Calculated %: Cl 20.56; S 18.55.

Literature data [5]: B.p. 108–110° (8 mm), d_4^{20} 1.1907, n_D^{20} 1.5868.

SUMMARY

The reaction of sulfenyl chlorides with trithioformaldehyde was studied and it was shown that unsymmetrical α-chlorosulfides were thus formed.

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SYNTHESIS OF ARYLIDENE DERIVATIVES OF PSEUDOTHIOHYDANTOIN AND THIAZOLIDINEDIONE

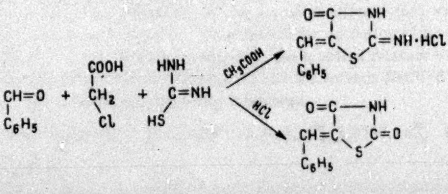
E.V. Vladzimirskaya

The arylidene derivatives of rhodanine $\mathrm{ArCH} = \underline{\mathrm{C} - \mathrm{S} - \mathrm{CS} - \mathrm{NH} - \mathrm{CO}}$ (1) are formed [1], as already known, by alkaline hydrolysis of arylthiopyroracemic acid $\mathrm{ArCH_2CSCOOH}$, and are valuable intermediates [2] for synthesizing β-arylalanines $\mathrm{ArCH_2CH(NH_2)COOH}$, arylacetonitriles $\mathrm{ArCH_2CN}$, arylacetic acids $\mathrm{ArCH_2COOH}$ and β-arylethylamines $\mathrm{ArCH_2CH_2NH_2}$. These substances may also be obtained by starting with the arylidene derivatives of pseudothiohydantoin $\mathrm{ArCH} = \underline{\mathrm{C} - \mathrm{S} - \mathrm{C(NH)} - \mathrm{NH} - \mathrm{CO}}$ or thiazolidinedione $\mathrm{ArCH} = \underline{\mathrm{C}-\mathrm{S}-\mathrm{CO}-\mathrm{NH}-\mathrm{CO}}$; but synthesis of the latter is more complicated and comprises two or more stages.

The arylidene derivatives of pseudothiohydantoin have been synthesized usually in two stages: 1) condensation of monochloroacetic acid or its ethyl ester with thiourea by Volhard's method [3,4]; and 2) condensation of the resulting pseudothiohydantoin with aromatic aldehydes [5]. For synthesizing the arylidene derivatives of thiazolidinedione pseudothiohydantoin is usually boiled [6] with hydrochloric acid and the resulting thiazolidinedione condensed with aromatic aldehydes.

In one of our previous communications [8] it was shown that, in boiling tibione, monochloroacetic acid, and various aldehydes in glacial acetic acid, the formation in one stage of complex arylidene derivatives of pseudothiohydantoin was observed.

In this work our purpose was to establish the optimum conditions for synthesizing the simplest arylidene derivative, namely: 5-benzylidenepseudothiohydantoin, and also its hydrolysis product, 5-benzylidenethiazolidindione, according to the scheme:



In order to study the raction of formation of 5-benzylidenepseudohydantoin in one stage we condensed monochloroacetic acid and benzaldehyde with varying amounts of thiourea for different time periods. The results showed that the yield of 5-benzylidenepseudothiohydantoin increased as the amount of thiourea introduced into reaction increased. At first the yield of reaction product increased rapidly and then very slowly. For obtaining good yields it is necessary to use at least 2 moles and not 1 mole of thiourea, per mole of monochloroacetic acid, as may be required from theoretical considerations. This condition causes partial breakdown of the thiourea when boiled with acetic and monochloroacetic acids, as is indicated by formation of hydrogen sulfide during the reaction. In studying the presence of thioglycolic acid, it was found that the latter may occur in the filtrate only in very small amounts. Condensation is practically completed even in 30 min of heating, since further boiling of the reaction mixture leads only to an insignificant increase in the yield of 5-benzylidenepseudothiohydantoin.

By using hydrochloric acid instead of acetic for the reaction we obtained 5-benzylidenethiazolidinedione in one stage, since hydrolysis of the NH group proceeded simultaneously with condensation. Experimental results show that in order to obtain a good yield of 5-benzylidenethiazolidinedione 2 moles thiourea per 1 mole monochloroacetic acid is adequate, whereby it is necessary to boil the reaction mixture for at least 4 hours. Excess hydrochloric acid lowers the yield, and is evidently associated with partial decomposition of the thiourea by the hydrochloric acid. The optimum amount of hydrochloric acid is 3-4 moles per 1 mole monochloroacetic acid. A larger amount of hydrochloric causes diminution in yield, while less should not be used because there would be insufficient liquid when boiling the reaction mixture. In order to increase the yield above 65% one can only resort to a prolonged period of heating during condensation.

It should be pointed out that methods of synthesizing 5-arylidene derivatives of thiazolidone-4 (rhodanine, pseudothiohydantoin etc.) in one stage, may have definite importance in the cinematograph [10] and chemical industries [11].

EXPERIMENTAL

Synthesis of 5-benzylidenepseudothiohydantoin. 12.5-100 mmoles thiourea, 25 mmoles monochloroacetic acid, 25 mmoles benzaldehyde and 15 ml glacial acetic acid were refluxed for various intervals of time. After cooling, sodium carbonate solution was added to alkaline reaction point for conversion of the 5-benzylidenepseudothiohydantoin hydrochloride to a free base. The residue was filtered, washed with water, and dried. Yields of condensation product are given in Table 1. Since 5-benzylidenepseudothiohydantoin has no definite m.p., the reaction product was identified by hydrolysis, whereby we obtained 5-benzylidenethiazolidinedione of m.p. 240° [9].

TABLE 1

Heating time 30 min		Amount of thiourea 50 mM	
mM Thiourea	Yield %	Heating time (min)	Yield %
0.5	8.8	15	66.4
1	27.4	30	76.0
2	75.6	60	76.2
4	81.3	120	80.0

Synthesis of 5-benzylidenethiazolidinedione. A mixture of 50 m moles monochloroacetic acid, 50 m moles benzaldehyde, 50-250 m moles thiourea and 150-600 m moles concentrated hydrochloric acid was refluxed for various time periods. At the start of the boiling a clear solution formed from which, with further heating, a precipitate separated. After cooling the reaction mixture was diluted with water, the precipitate filtered, washed with water, and dried. Yields of condensation product are shown in Table 2.

TABLE 2

Heating time 1 hr, with 320 mMoles hydrochloric acid		Heating time 2 hrs, with 50 mMoles thiourea		100 mM thiourea, 320 mMoles hydrochloric acid	
mmoles thiourea	Yield %	mmoles hydrochloric acid	Yield %	Heating time in hrs.	Yield %
50	38.5	150	64.5	0.25	38.1
100	50.0	200	64.5	0.5	43.4
125	50.3	400	49.0	1	51.2
150	56.7	600	46.0	2	61.1
200	50.7			4	69.0
250	46.2			6	69.2

The 5-benzylidenethiazolidinedione obtained by us was a light yellow substance of fairly high purity, since its m.p. was about 235° (without recrystallization). After once recrystallizing from alcohol a colorless substance was obtained of m.p. 240°, corresponding to literature data [9].

We must acknowledge the kindness of N. M. Turkevich for valuable help in carrying out the present work.

SUMMARY

1. 5-Arylidene derivatives of pseudothiohydantoin may be obtained in one stage by heating thiourea, monochloroacetic acid and aromatic aldehydes in acetic acid.

2. A similar condensation in concentrated hydrochloric acid leads to formation of 5-arylidene derivatives of thiazolidindione.

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*Russian translation.

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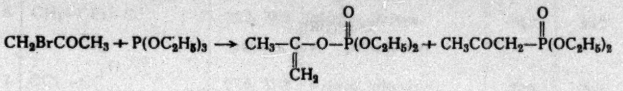
ANOMALOUS REACTION OF α-HALOKETONES WITH ESTERS OF PHOSPHOROUS ACID

VI. REACTIONS OF ESTERS OF PHOSPHOROUS ACID WITH HALIDES OF HALO-SUBSTITUTED CARBOXYLIC ACIDS

A.N. Pudovik and L.G. Biktimirova

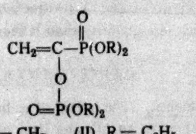
Reactions of acyl halides with esters of phosphorous acid, as has been found by M. I. Kabachnik and P. A. Rossiiskaya [1] and by A. E. Arbuzov and M. M. Azanovskaya [2] proceed in accord with Arbuzov's regrouping scheme and lead to the formation of ketophosphinic esters. As we have shown in our previous work [3-9], the reactions of various α-haloketones, α-haloderivatives of acetylacetone, acetoacetic ester, etc., with phosphites occur with formation either of mixtures of phosphines and unsaturated esters of phosphoric acid, or the latter only. In the case of bromoacetone, for example, the reaction proceeds as follows:



$$CH_2BrCOCH_3 + P(OC_2H_5)_3 \longrightarrow CH_3{-}\underset{\underset{CH_2}{\|}}{C}{-}O{-}\overset{\overset{O}{\|}}{P}(OC_2H_5)_2 + CH_3COCH_2{-}\overset{\overset{O}{\|}}{P}(OC_2H_5)_2$$

In connection with the experimental work, it appeared to be of interest to us to study the reactions of phosphites with halides of halosubstituted carboxylic acids, It might be supposed that the halosubstituted ketophosphinic esters forming in the first stage of the reaction, owing to the strong polarizing effect of the halogen and phosphinic group on the carbon atom of the carbonyl group, would react with the phosphites either entirely or mainly by way of an anomalous mechanism. Experiments have confirmed this supposition.

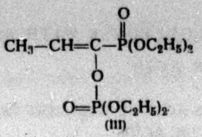
We have studied the reactions of triethyl phosphite and trimethyl phosphite with the chlorides of chloroacetic and trichloroacetic acids and with the bromides of bromopropionic and α-bromoisobutyric acids. The 1-(dimethylphosphonium)ethenyl-dimethyl phosphoric ester (I) and 1-(diethylphosphonium)ethenyl-diethyl phosphoric ester (II) were obtained by reacting triethyl phosphite and trimethyl phosphite with chloroacetyl chloride. The structure of (I) and (II) was confirmed by ozonizing. In both cases formaldehyde was identified.



$$CH_2{=}\underset{\underset{\underset{\underset{O{=}P(OR)_2}{|}}{O}}{|}}{C}{-}\overset{\overset{O}{\|}}{P}(OR)_2$$

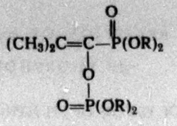
(I) $R = CH_3$, (II) $R = C_2H_5$

There was no indication of phosphinic esters with higher boiling points. The attempt was made to separate the intermediate product of reaction of triethyl phosphite with chloroacetyl chloride. To this end the reaction was carried out very slowly in ether solution with constant cooling. But it was not possible to separate out the chlorosubstituted acetophosphinic ester; only the ester (II) was obtained. Reactions of esters of phosphorous acid with the bromides of α-bromo-substituted carboxylic acids were completely anomalous. In the reaction of triethyl phosphite with α-bromopropionic bromide only 1-(diethylphosphonium)propenyl-1-diethyl phosphoric ester (III) was obtained. In ozonizing (III) acetaldehyde was identified. In similar reaction with α-bromoisobutyric acid bromide only anomalous products were again obtained; with trimethyl phosphite, 1-(dimethylphosphonium) isobutenyl-1-dimethyl phosphoric ester (IV), and with triethyl phosphite, 1-(diethylphosphonium) isobutenyl-1-diethyl phosphoric ester (V):



$$CH_3-CH=C(-O-P(=O)(OC_2H_5)_2)-\overset{O}{\overset{\|}{P}}(OC_2H_5)_2$$

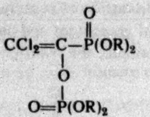
(III)



$$(CH_3)_2C=C(-O-P(=O)(OR)_2)-\overset{O}{\overset{\|}{P}}(OR)_2$$

(IV) $R=CH_3$, (V) $R=C_2H_5$

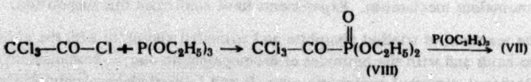
Reactions of phosphorous esters with trichloroacetic acid chloride proceed very vigorously. In carrying out the reactions without solvent with trimethyl phosphite only 1-(dimethylphosphonium)dichloroethenyl-dimethyl phosphoric ester (VI) was obtained; and with triethyl phosphite, only 1-(diethylphosphonium)dichloroethenyl-diethyl phosphoric ester (VII).



$$CCl_2=C(-O-P(=O)(OR)_2)-\overset{O}{\overset{\|}{P}}(OR)_2$$

(VI) $R=CH_3$, (VII) $R=C_2H_5$

In carrying out the reaction of triethyl phosphite with trichloroacetic acid chloride, ester (VII) and the diethyl ester of trichloroacetophosphinic acid (diethyltrichloroacetophosphinate) (VIII), we obtained both products in approximately equal amounts. In product (VIII), the carbonyl group was quantitatively determined; in (VII), it was absent. The reactions, therefore, proceeded as follows:



$$CCl_3-CO-Cl+P(OC_2H_5)_3\longrightarrow \underset{(VIII)}{CCl_3-CO-\overset{O}{\overset{\|}{P}}(OC_2H_5)_2}\xrightarrow{P(OC_2H_5)_3}(VII)$$

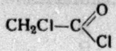
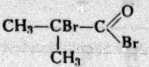
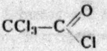
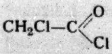
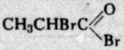
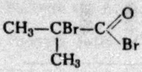
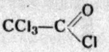
It is evident that in all the other cases studied by us, reaction proceeds with formation of haloalkylphosphonium ketones as intermediate products; but owing to their great reactivity they quickly react further with the phosphite, forming unsaturated phosphoric esters. A similar sequence of reactions was observed also in the case when the phosphite was used in much less quantity than is required by the relevant equation.

EXPERIMENTAL

Methods of conducting the experiments. The halide of α-halosubstituted acid was gradually added from a dropping funnel to the phosphite contained in an Arbuzov flask connected to a reflux condenser. The reactions were accompanied by considerable heat evolution. In the case of strongly exothermic reactions, the acyl halide was added very slowly and the reaction flask cooled with water. After all the acyl halide had been added, the reaction mixtures were either immediately distilled in vacuum or further heated over the water bath. Completion of reaction was indicated when methyl and ethyl chloride or bromide ceased to separate. When the reaction was done in ether solution, the latter was heated over the water bath, the ether distilled off, and the residue redistilled in vacuum. Experimental conditions and product yields are given in Table 1. Characteristics of products obtained are shown in Table 2.

TABLE 1

Reactions of Phosphites with Halides of α-Halosubstituted Carboxylic Acids

No.	Interacting Reagent	Amount of phosphite and reagent (in g)	Conditions of reaction	Product yield	
				(g)	(%)
	Reactions of trimethylphosphite				
1	 $CH_2Cl-C\begin{smallmatrix}O\\ Cl\end{smallmatrix}$	30.7, 14.0	Heating 0.5 hr at 100°	27	84
2	 $CH_3-\underset{CH_3}{\underset{\vert}{C}}Br-C\begin{smallmatrix}O\\ Br\end{smallmatrix}$	24.8, 23	Heating 0.5 hr at 85°	26.6	92.3
3	 $CCl_3-C\begin{smallmatrix}O\\ Cl\end{smallmatrix}$	27.5, 20.18	Cooling. Temp. not >30°	28.6	78.3
	Reactions of triethylphosphite				
4	 $CH_2Cl-C\begin{smallmatrix}O\\ Cl\end{smallmatrix}$	35, 11.3 16.6, 11.3	Without solvent In ether	27.3 11.3	86.4 —
5	 $CH_3CHBrC\begin{smallmatrix}O\\ Br\end{smallmatrix}$	18.0, 10.8	At 100° without solvent	14.1	78.6
6	 $CH_3-\underset{CH_3}{\underset{\vert}{C}}Br-C\begin{smallmatrix}O\\ Br\end{smallmatrix}$	33.2, 23.0	Without solvent	31.2	90.7
7	 $CCl_3-C\begin{smallmatrix}O\\ Cl\end{smallmatrix}$	57.6, 31.6 34.0, 18.0	Without solvent In ether	47.8 15.9*	78.6 —

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* Two products were obtained: trichloroacetophosphinic ester (8.3 g) and 1-(diethylphosphonium)dichloroethenyl-diethyl phosphoric ester (7.6 g)

Ozonizing 1-(diethylphosphonium)ethenyl-diethyl phosphoric ester. A solution of 3 g of the phosphoric ester under test in 20 ml anhydrous carbon tetrachloride was blown with ozonized oxygen for 20 hours. After removal of the solvent under vacuum the ozonides were decomposed with water and heating. The formaldehyde thus formed was identified as a condensation product with dimedon, of m.p 189° (mixed sample 189-190°), and as dinaphtholmethane of m.p. 194-196° (mixed sample 195-196°).

Ozonizing 1-(dimethylphosphonium)ethenyl-dimethyl phosphoric ester. Ozonizing and decomposition of ozonides proceeded as above. The formaldehyde separating from the ozonide was identified as dinaphtholmethane, of m.p. 194-195° (mixed sample 195-196°).

Ozonizing 1-(diethylphosphonium) propenyl-1-diethyl phosphoric ester. Acetaldehyde, formed by breakdown of the ozonide with water, was identified as a condensation product with dimedon, of m.p. 139-140° (mixed sample 140-141°).

TABLE 2

Data on the Obtained Reaction Products

No.	Name of substance	Formula	B.p. (pressure in mm)	d_4^{20}	n_D^{20}	MR_D		Analysis results (%)			
								P		Cl	
						found	calculated	found	calculated	found	calculated
1	1-(dimethylphosphonium)-ethenyl-dimethyl phosphoric ester	$C_6H_{14}O_7P_2$	141° (1)	1.3214	1.4420	52.06	52.30	24.10	23.85	—	—
2	1-(dimethylphosphonium)-isobutenyl-1-dimethyl phosphoric ester	$C_8H_{18}O_7P_2$	131—132 (0.5)	1.2756	1.4580	61.60	61.53	21.43	21.52	—	—
3	1-(dimethylphosphonium)-dichlorethenyl-dimethyl phosphoric ester	$C_6H_{12}O_7Cl_2P_2$	134—135 (0.75)	1.4901	1.4770	62.32	62.03	18.82	18.84	22.00	21.58
4	1-(diethylphosphonium*) ethenyl-diethyl phosphoric ester	$C_{10}H_{22}O_7P_2$	125—126 (0.5)	1.1827	1.4396	70.26	70.76	19.30	19.62	—	—
5	1-(diethylphosphonium)** propenyl-1-diethyl phosphoric ester	$C_{11}H_{24}O_7P_2$	128—129 (1.5)	1.1690	1.4450	75.07	75.38	18.86	18.78	—	—
6	1-(diethylphosphonium)isobutenyl-1-diethyl phosphoric ester	$C_{12}H_{26}O_7P_2$	134—135 (1.5)	1.1602	1.4503	79.68	80.00	18.29	18.57	—	—
7	1-(diethylphosphonium)dichlorethenyl-diethyl phosphoric ester	$C_{10}H_{20}O_7Cl_2P_2$	132—133 (0.5)	1.3219	1.4660	80.66	80.50	16.25	16.10	19.27	18.49
8	Diethyl-trichloracetophosphinate***	$C_6H_{10}O_4Cl_3P$	95 (2)	1.3916	1.4632	56.09	55.38	11.30	10.93	37.46	37.56

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* Unsaturation 82% (per McIlvaine).

** Unsaturation 100% (per McIlvaine).

*** Found %: CO 9.13. Calc. %: CO 9.88 (by method of Terentyev and Zabrodina [10]).

**** Mean of two determinations.

SUMMARY

1. The reactions of esters of phosphorous acid with chloroacetic and trichloroacetic acid chlorides and with bromopropionic and α-bromoisobutyric acid bromides have been studied. In all cases the reactions proceeded with formation of unsaturated esters of phosphoric acids.

2. From the example reaction of trichloroacetylchloride with triethyl phosphite it was shown that the reaction proceeds in two stages. In the first phase the halosubstituted acylhalide reacts with the phosphite according to Arbuzov's regrouping scheme with formation of the haloalkylphosphonium ketone. This latter, owing to its reactivity, in most cases quickly reacts with a second phosphite molecule. The reaction proceeds by the anomalous mechanism with formation of the unsaturated phosphoric ester.

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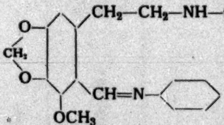
SOME QUESTIONS ON THE STRUCTURE OF COTARNINE DERIVATIVES

II. STRUCTURE OF CONDENSATION PRODUCTS OF COTARNINE WITH COMPOUNDS CONTAINING NITROGEN

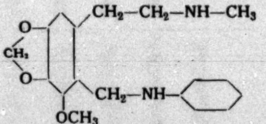
Denesh Beke and Kalman Kharshani

Cotarnine gives condensation products with many compounds containing nitrogen, with which aldehydes also react with splitting off of water: with aromatic amines "anils" [1,2], with hydrosilamine "oxime" [3], with acid amides "anhydrocotarnine compounds" [2,4], with phenylhydrazine the derivative thereof was obtained by us for the first time. These reactions may serve generally as indicating the existence of the aminoaldehyde form of cotarnine, and the reaction products formed may be regarded as derivatives of 2-(β-N-methylamino-ethyl)-benzaldehyde, although Dobbie, Lauder and Tinkler [5] found the ultraviolet spectrum of "cotarnine-oxime" in ether and chloroform identical with those of hydrocotarnine and 1-cyanohydrocotarnine. Gensler [6] noted the possibility of cyclic chain tautomerism, but on the question of structure does not express an opinion.

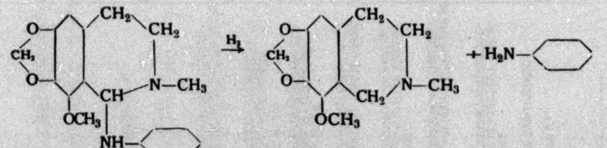
Within the limits of our research we subjected "cotarninanil" to catalytic hydrogenation, in which the substance combined 1 M of hydrogen with great rapidity; but instead of substituted phenylbenzylamine (II), anticipated from the configuration with open chain (I), we obtained nearly theoretical yield of hydrocotarnine (III) and aniline. Under similar conditions the "cotarnine-oxime" (V), the phenylhydrazine derivative (VI), "anhydrocotarnine-urea" (VII), and 1-phthalimidohydrocotarnine (VIII) [4] which doubtless has a ring structure—undergo hydrogenolithic splitting, and yield, besides hydrocotarnine, ammonia, phenylhydrazine , , urea, or phthalimide. These compounds are very easily decomposed, even under the action of sodium bisulfite, and in this case, instead of hydrocotarnine with good yield, hydrocotarnine-1-sodium sulfonate [7] is obtained.



(I)

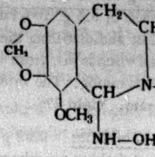


(II)

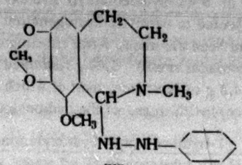


(IV) (III)

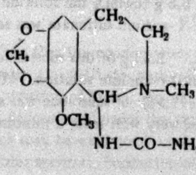
Hydrogenolysis of the above-named cotarnine derivatives, as also their decomposition under the action of sodium bisulfite, may be most simply explained from their cyclic structure (IV-VIII). It was possible to show this, moreover, by the spectroscopic method. The ultraviolet spectrum of a benzene solution of these compounds did not exhibit any absorption maximum, characteristic of the double bond present in conjunction with an aromatic ring. For the "oxime" a cyclic structure is indicated also by the fact that it forms, besides the monohydrochloride described in the literature [3], also the dihydrochloride, and that its hydrogenation proceeds very quickly, similar to that of the "anil." Under such conditions N-benzoyl-cotarnine oxime [2], which is doubtless a compound with open chain and is moreover essentially an oxime, is not hydrogenated.



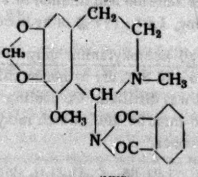
(V)



(VI)



(VII)



(VIII)

All these condensation products of cotarnine are, without exception, derivatives of hydrocotarnine substituted in position 1. Accordingly also their names should be amended to 1-anilinohydrocotarnine, β-(1-hydrocotarnyl)-hydroxylamine, α-(1-hydrocotarnyl)-β-phenylhydrazine, and 1-ureidohydrocotarnine. Instability of the compounds naturally follows from their heminal diamino structure; their formation accords very well with the cyclic structure of cotarnine, and does not involve the necessity of assuming therein an aminoaldehyde form.

EXPERIMENTAL

1-Anilinohydrocotarnine ("cotarninanil," IV). 23.7 g cotarnine was pulverized in a porcelain mortar with 9.3 g aniline and 30 ml water. After some minutes stirring a pasty substance was obtained which, on standing, gradually solidified. At the end of 4 hours it was separated, washed with water, and dried in a vacuum-desiccator. Yield 29.7 g (95%) of crude product of m.p. 114-116°. After recrystallizing from light benzine a light cream-colored substance is obtained of m.p. 124°.

Hydrogenation of 1-anilinohydrocotarnine. 9.36 g of this substance was dissolved in 70 ml ethylacetate and subjected to catalytic hydrogenation in the presence of 0.7 g of 10% Pd on carbon. Hydrogen absorption was extremely rapid: 90% of the calculated amount of hydrogen was absorbed within the first 15 min. After filtering the catalyst and distilling off the solvent 9.8 g remained of a yellowish-brown oil, which was distilled under 2.5 mm and divided into two fractions. The fraction distilling at 47-50° (2.05 g) proved to be aniline (from b.p. 183° under atmospheric pressure, from the m.p. of its acetyl derivative, 113°, and from its thiourea derivative, formed from phenylic mustard oil, of b.p. 152-153°). The fraction boiling at 154-156° (2.5 mm) was obtained up to 5.35 g, and solidified on cooling; m.p. 51-52°; m.p. of picrate 175-177°; also analysis of its hydrochloride clearly showed its identity with hydrocotarnine (III).

Found %: C 55.89; H 6.06; N 5.62. $C_{12}H_{15}O_3N \cdot HCl$.
Calculated %: C 55.92; H 6.26; N 5.43.

Reaction of 1-anilinohydrocotarnine with sodium bisulfite. 1.56 g of substance was dissolved in a solution of 0.52 g $NaHSO_3$ in 10 ml water, whereby separation of an oil was observed that, in smell, resembled aniline. After adding a further 0.52 g $NaHSO_3$ the solution was heated to b.p. and treated with animal charcoal. After cooling the solution to 50° and adding 5 g $NaHSO_3$ cloudiness was very soon observed, and a large quantity of crystalline substance began to separate. On the following day the mass was suction-filtered, washed with a small quantity of alcohol, and dried. Yield 1.47 g (91%) of hydrocotarnine-1-sodium sulfonate.

β-(1-Hydrocotarnyl)-hydroxylamine ("cotarnine oxime" V). 10.5 g hydroxylamine hydrochloride was added to a solution of 16.8 g $NaHCO_3$ in 40 ml water. When no more CO_2 separated the filtered solution was mixed with 50 ml alcohol, and after adding 23.7 g cotarnine it was boiled for half an hour over the water-bath. In a short time yellow compact crystals began to appear, and after cooling with ice these were separated. Yield 19.2 g (76.5%), of m.p. 157°.

Hydrogenation of β-(1-hydrocotarnyl)-hydroxylamine. 5.04 g oxime (V) was dissolved in 150 ml tetrahydrofurane, and subjected to catalytic hydrogenation in the presence of 0.5 g 10% Pd on carbon. In $1^1/_2$ hour 0.039 M hydrogen had been absorbed. After filtering off the catalyst and distilling the solvent from solution (having a sharp ammoniacal smell), 5.48 g remained of a light red viscous oil, from which was distilled at 127-131° (0.5 mm) 4.3 g of substance, most of which solidified on standing. The substance was found to be hydrocotarnine in accord with m.ps. of the hydrochloride and picrate. Yield 97%.

Reaction of β-(1-hydrocotarnyl)-hydroxylamine with sodium bisulfite 0.52 g $NaHSO_3$ was added to a suspension of 1.27 g of this substance in 12 ml water, with prolonged shaking up, whereby a perfectly clear solution was obtained. After addition and solution of a further 3.5 g $NaHSO_3$ the solution was quickly filtered from admixture. After standing, 1.57 g (97%) of hydrocotarnine-1-sodium sulfonate was separated from the filtrate.

β-(1-hydrocotarnyl)-hydroxylamine dihydrochloride. 2.52 g of this substance was heated in 10 ml anhydrous alcohol with 5 g of 30% dry hydrogen chloride until complete solution. After separating from admixture half the solvent was distilled. On cooling 2.04 g (77.5%) of substance was separated, consisting of needle-shaped crystals of m.p. 96-100°, which recrystallized very well from a mixture of alcohol and ethylacetate or from butyl alcohol.

Found %: N 8.57; Cl 21.65. $C_{12}H_{16}O_4N_2\cdot 2HCl$.
Calculated %: N 8.62; Cl 21.82.

α-(1-Hydrocotarnyl)-β-phenylhydrazine, (VI). 4.5 g of phenylhydrazine hydrochloride and 4.8 g crystalline sodium acetate were dissolved in 45 ml water with moderate heating. 7.11 g cotarnine was added to the solution after cooling, and this dissolved within a few minutes; then a 10% solution caustic soda was added dropwise until phenolphthalein gave an alkaline reaction. A sticky, greasy substance separated, which solidified when triturated with ether. Weight of crude product was 9.34 g (95%). It is desirable to use the product at once, as it decomposes on standing. The substance, which recrystallized from light benzene (b.p. 40-100°) melted at 80-82°.

Found %: N 13.12. $C_{18}H_{21}O_3N_3$.
Calculated %: N 12.84.

Hydrogenation of α-(1-hydrocotarnyl)-β-phenylhydrazine. 5.9 g of the crude substance, freshly prepared, dissolved in 45 ml ethylacetate, was catalytically hydrogenated in the presence of palladium on carbon. Hydrogen absorption ceased in 2 hours, and amounted to 0.0172 M. The product remaining after removing catalyst and distilling off the solvent (5.28 g), was distilled in vacuum. 1.3 g of substance was obtained, distilling at temperature up to 120° (2.1 mm). This was further treated with an aqueous acetic solution of benzaldehyde, and gave 1.60 g of crystalline product of m.p. 154-155° (from ethanol), without depression in a test mixing with benzaldehyde phenylhydrazone. The colorless oil redistilled at 147-150° (2.1 mm) was identified – as hydrochloride and picrate – with hydrocotarnine.

Ureidohydrocotarnine "anhydrocotarnine-urea," (VII) - 2.79 g of this substance, prepared according to Dey and Kantam, in 30 ml butyl alcohol, was hydrogenated in the presence of 0.2 g palladium on carbon as catalyst. The substance, at first suspended in the solvent, was gradually dissolved during hydrogen absorption. This absorption up to 0.096 M ceased in 2 hours. After removal of catalyst and distilling solvent (in vacuum) 2.21 g remained that was first extracted in 10 ml water and then twice in 10 ml ether. After drying and adding anhydrous alcoholic hydrochloric acid, 2.09 g of hydrocotarnine hydrochloride was obtained from the ether solution. On evaporating the aqueous solution and adding 1 g oxalic acid dissolved in 10 ml water, crystals separated of m.p. 177°, without depression in a test mixing with urea oxalate.

Reaction of 1-ureido-hydrocotarnine with sodium bisulfite. 1.40 g of the substance was suspended in 22 ml water, and dissolved after adding 8 g $NaHSO_3$ with heating up to 40-50°. On cooling the solution and filtering off admixtures 1.58 g of hydrocotarnine-1-sodium sulfonate crystallized out.

1-Phthalimidohydrocotamine (VIII). 2.37 g cotamine was added to a solution of 1.50 g phthalimide in 30 ml ethanol at 40°. After a time crystals in considerable quantity separated. Yield of 1-phthalimidohydrocotamine was 1.77 g (48.5%) of m.p. 127°.

Hydrogenation of 1-phthalimidohydrocotamine. 1.83 g of this substance in 30 ml tetrahydrofurane was catalytically hydrogenated in the presence of palladium on carbon. It was completed in 20 min with 0.005 M hydrogen absorption. After removing catalyst and distilling solvent the residue (1.77 g) was dissolved in 10 ml ethanol. On cooling with ice 0.523 g of crystalline substance of m.p. 231-233° was separated, and showed no depression with phthalimide. After addition of anhydrous alcoholic hydrochloric acid 0.99 g of hydrocotarnine hydrochloride was separated from the filtrate.

We extend our thanks to G. Zemplen for his continued interest in the work, I. Batta for undertaking the microanalyses, Yu. Varshani for taking and developing the ultraviolet spectra, and Yu. Vadas for valuable help in the experiments.

SUMMARY

It has been established that the condensation products of cotarnine with various nitrogen-containing compounds, regarded as derivatives of 2-(β -N-methylaminoethyl)-benzaldehyde, by catalytic hydrogenation, undergo hydrogenolysis, with formation of hydrocotarnine and the corresponding nitrogen-containing compound. They are also very easily decomposed under the action of $NaHSO_3$, with formation of hydrocotarnine-1-sodium sulfonate. These reactions may be explained on the basis of the cyclic structure of the compounds, as is also indicated by their ultraviolet spectra. Formation of the compounds agrees very well with the cyclic structure of cotarnine, and does not involve the need for assuming for this an aminoaldehyde configuration.

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* Original Russian pagination. See C. B. translation.

SYNTHESIS AND CONVERSIONS OF PYRIMIDINE DERIVATIVES

VIII. THE SYNTHESIS OF CYTOSINE

R. S. Karlinskaya and N. V. Khromov-Borisov

Cytosine (2-hydroxy-4-aminopyrimidine) was separated from ribonucleic acid in 1894 [1]. It was first obtained synthetically by Wheeler and Johnson [2], who definitely established its structure. Cytosine presents special interest at the present time in view of the fact that it has been found to be a strong cytostat (data of G. I. Felistovich), which may be of value in the treatment of such serious disorders of the blood as leucosis.

As starting materials for the synthesis of cytosine two substances come to mind, namely: uracil and dithiouracil. A scheme for the conversion of uracil into cytosine, described in the literature [3, 4], provides for the preparation of 2,4-dichloropyrimidine, in which, by the action of dilute ammonia in anhydrous alcohol one chlorine atom is substituted in the amino group. In this way, however, two isomers are formed: 2-amino-4-chloro- and -2-chloro-4-aminopyrimidine, that are separable with much difficulty. The chloro-aminopyrimidines, therefore, are converted by the action of sodium methylate into a mixture of the corresponding methoxyaminopyrimidines that is separated by recrystallization from water. Hydrolysis of 2-methoxy-4-aminopyrimidine by concentrated hydrochloric acid produces cytosine.

The synthesis of cytosine from dithiouracil was worked out by Hitchings and further improved by Brown [5]. The dithiouracil required for this may be prepared either by reacting 2,4-dichloropyrimidine with thiourea in alcohol [6], or from thiouracil by the action thereon of phosphorus pentasulfide [5]. Treatment of dithiole with ammonia yields 2-mercapto-4-aminopyramidine (in this case without admixture of the isomer), which is further concentrated with chloroacetic acid, and the product in turn hydrolyzed with hydrochloric acid, thus producing cytosine.

A comparative evaluation of both methods undertaken by us showed that the basic defect of Hilbert's method was the difficulty of separating the isomers, since it is practically impossible to separate the mixture of chloroaminopyrimidines. A sufficient degree of separation of the isomeric methoxyaminopyrimidines can be achieved only after several recrystallizations from water; and this is accompanied by heavy losses. As a result the yield of 2-methoxy-4-aminopyrimidine, and therefore also cytosine, turns out to be inappreciable. Moreover, according to the author cited, the ratio of isomers in the mixture obtained is unfavorable: the content of 2-amino-4-methoxypyrimidine therein is 1½ times larger than that of the 2-methoxy-4-aminopyrimidine.

A fundamental defect in Brown's method is the prolonged duration and relative complexity of the conversion stages of dithiouracil into 2-mercapto-4-aminopyrimidine (thiocytosine): it was necessary to pass gaseous ammonia for 25-30 hours into the aqueous solution of dithiole heated to boiling temperature. Furthermore, the lack of clear and definite constants for both compounds (dithiole and thiocytosine) impedes control of the reaction end point. Thus, as a result of the check undertaken, it appeared that the more convenient and simpler method of Hilbert proved to be of little use owing to the absence of a reliable procedure in separating the isomeric methoxyaminopyrimidines.

We were able to develop a method permitting clean and definite separation of 2-amino-4-methoxypyrimidine from 2-methoxy-4-aminopyrimidine. For this purpose the mixture of methoxy aminopyrimidines was treated in the cold with dioxan, in which the 2-amino-4-methoxypyrimidine was easily soluble, while the 2-methoxy-4-aminopyrimidine was nearly insoluble. Moreover, it appeared possible, by using in the process of reacting with 2,4-dichloropyrimidine 25% aqueous ammonia instead of alcoholic, to ensure increase in the relative content of 2-chloro-4-aminopyrimidine in the resulting mixture of chloroaminopyrimidines.

As a result, after methoxylating, a mixture is obtained containing 65% 2-methoxy-4-aminopyrimidine and 35% 2-amino-4-methoxypyrimidine. By using dioxan for separating this mixture we obtained, after hydrolysis, cytosine with a yield of 45-50% (reckoned as 2,4-dichloropyramidine). The solution of 2-amino-4-methoxypyrimidine in dioxan may be used also for obtaining isocytosine.

EXPERIMENTAL

Production of mixed 2-chloro-4-aminopyrimidine and 2-amino-4-chloropyrimidine. 10 g 2,4-dichloropyrimidine and 25 ml of 25% aqueous ammonia were shaken up for 1-2 hours, and left to stand for 3-3½ days at 17-20°. The precipitate of mixed chloroaminopyrimidines was filtered, washed with 15 ml water, dried somewhat, and washed again with ether. Yield 7-7.5 g (75-87%).

Production of 2-methoxy-4-aminopyrimidine and 2-amino-4-methoxypyrimidine. 7 g of the mixed chloraminopyrimidines obtained in the preceding experiment was heated over thewater bath for 4-5 hours with a solution of sodium methylate prepared from 1.4 g sodium and 200 ml of methyl alcohol. After cooling, the precipitated sodium chloride was filtered off, the methyl alcohol distilled, and the residue washed once with 10 ml water. The yield was 6-6.5 g (92-97%). The substance was then twice treated with cold dioxane (5 ml each time), washed on the filter with 2-3 ml dioxan , and dried at 50°. Weight of residue (2-methoxy-4-aminopyrimidine) was 3.8-4.2 g (57-61%); m.p. 167-170° (with preliminary softening). The dioxane was distilled off, and the residue (1.8-2.0 g) of 2-amino-4-methoxypyrimidine was crystallized from water. M.p. 118-120°*.

Production of cytosine hydrochloride. 4.0 g 2-methoxy-4-amino pyrimidine was dissolved in 20 ml concentrated hydrochloric acid and the solution evaporated to dryness. The crystalline residue, cytosine hydrochloride** thus formed was pulverized and washed with alcohol. M.p. 267-268°. Yield 4.2 g (93%).

SUMMARY

1. The methods of Hilbert and Brown for obtaining cytosine as described in the literature, have been compared.

2. Methods have been proposed for removing the defects in that of Hilbert: a) Amination of dichloropyrimidine with 25% aqueous ammonia at 17-20°; b) separation of 2-methoxy-4-aminopyrimidine and 2-amino-4-methoxypyrimidine by means of dioxan.

3. Modified in this way Hilbert's method permits the simple and reliable preparation of cytosine with a yield of 45-50% (reckoned on the initial 2,4-dichloropyrimidine).

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* If after two treatments with dioxan the m.p. of 2-methoxy-4-aminopyrimidine proves to be below 167° the dioxan treament must be repeated.

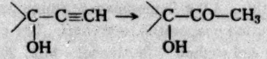
** 2-Amino-4-methoxypyrimidine may be converted in a similar manner into isocytosine hydrochloride. The yield of cytosine, reckoned on the 2,4-dichloropyrimidine is 45-50%.

ACETYLENE DERIVATIVES

185. HYDRATION OF DIMETHYLVINYLETHINYLCARBINOL ACETATE. SYNTHESIS AND CONVERSION OF UNSATURATED α-ACETOXY KETONES, I.

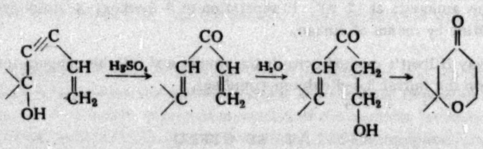
I.N. Nazarov and S.G. Matsoyan

The hydration of acetylenic hydrocarbons in the presence of mercury salts, discovered by Kutcheroff, was subsequently extended to a wide and varied range of acetylene compounds. Monosubstituted derivatives of acetylene, as a rule, are hydrated selectively with formation of methyl ketones [1]. Disubstituted acetylene compounds are usually hydrated in both the theoretically possible directions, with formation of mixed isomeric ketones [2]. As is known, acetylenic alcohols are very easily hydrated in the presence of mercuric sulfate, according to Kutcheroff, into the corresponding acetylene carbinols [1].



$$>\underset{OH}{\underset{|}{C}}-C\equiv CH \rightarrow >\underset{OH}{\underset{|}{C}}-CO-CH_3$$

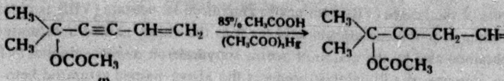
As has been shown by I. N. Nazarov and co-workers, vinylacetylene alcohols, unlike the acetylene alcohols, under the conditions of Kutcheroff's reaction, are isomerized first of all into divinyl ketones, which take up water through the nonsubstituted vinyl group, and are converted by way of unsaturated β-keto-alcohols into tetrahydro-γ-pyrones [3].



In the present work it was proposed to accomplish hydration of the triple bond of the vinylethinyl carbinols in such manner that their isomerization is prevented, and therefore to preserve the hydroxyl group of these carbinols. The conditions of the hydration reaction were studied in detail for dimethylvinylethinyl carbinol by way of example, and also for its ethers and esters.

The easily saponified esters of dimethylvinylethinyl carbinol, under the conditions of hydration in the presence of mercuric sulfate, were subjected to hydrolysis and isomerization, with formation of the conversion products of β,β-dimethyldivinyl ketone. More especially the ethers of dimethylvinylethinyl carbinol, in aqueous solutions, of the corresponding alcohols in the presence of mercuric sulfate, give β,β-dimethylvinyl-β-alkoxyethyl ketones [4]. But our observations showed that, by replacing mercuric sulfate with mercuric acetate, the acetate of dimethylvinylethinyl carbinol in 80% acetic acid solution at temperatures up to 75°, is hardly saponified at all. Moreover, the rate of isomerization of the carbinol in the presence of mercuric acetate falls sharply. Thus, the use of mercuric acetate (instead of the sulfate) creates conditions under which it is possible to achieve normal hydration of the dimethylvinylethinyl carbinol acetate without hydrolysis and isomerization.

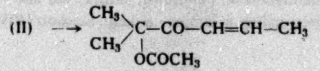
In this case, as we have found, the addition of water to the acetylene bond proceeds only in one direction, with formation of α-acetoxy ketone only. Actually the hydration of this acetate (I) in 80-95% acetic acid in the presence of mercuric acetate at 35-45°, gives only the acetate of dimethyl-(vinylacetyl) carbinol (II), with yield up to 70%:



$$\begin{matrix}CH_3\\CH_3\end{matrix}\!\!>\!\underset{\displaystyle OCOCH_3}{C}-C\equiv C-CH=CH_2 \xrightarrow[(CH_3COO)_2Hg]{85\%\ CH_3COOH} \begin{matrix}CH_3\\CH_3\end{matrix}\!\!>\!\underset{\displaystyle OCOCH_3}{C}-CO-CH_2-CH=CH_2$$

(I) (II)

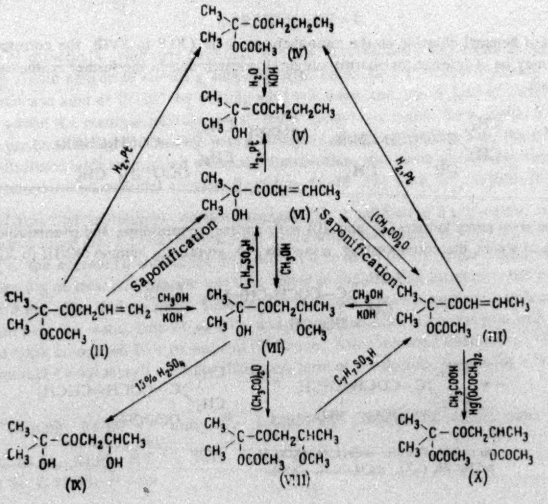
Raising the temperature of hydration up to 75° facilitates isomerization of the allyl ketone formed (II) into the more stable propenyl ketone (III), the relative amount of which depends also on duration of reaction, amount of catalyst, and acetic acid concentration. The adaptability of the allyl ketone (II) for isomerization into the propenyl ketone (III) was indicated by our special experiments. The acetate of dimethyl-(vinylacetyl) carbinol (II), on boiling in acetic acid solution in the presence of mercuric- or sodium acetate, is quantitatively isomerized into dimethylcrotonyl carbinol acetate (III). In the presence of mercuric asulfate, sulfuric acid, or p-toluenesulfonic acid this isomerization proceeds quantitatively even at 45-55°.



$$(II) \longrightarrow \begin{matrix}CH_3\\CH_3\end{matrix}\!\!>\!\underset{\displaystyle OCOCH_3}{C}-CO-CH=CH-CH_3$$

(III)

Hydrogenation of the allyl ketone (II) and of the propenyl ketone (III) proceeds very easily in the presence of a Pt catalyst, and leads to formation of the same saturated α-acetoxy ketone (IV), and from this by saponification with alcoholic alkali the saturated α-keto-alcohol is readily formed (V). Saponification of the unsaturated α-acetoxy ketones (II) and (III), both in acid and in alkali medium produces only dimethylcrotonyl carbinol (VI), and, accordingly, the allyl α-acetoxy ketone (II) in the reactions of alkaline saponification and acid hydrolysis undergoes simultaneous isomerization and displacement of the double bond into the conjugated


(CH3)2C(OCOCH3)-COCH2CH2CH3 (IV)
H2O KOH
(CH3)2C(OH)-COCH2CH2CH3 (V)
H2,Pt
(CH3)2C(OH)-COCH=CHCH3 (VI)
H2,Pt
H2,Pt
Saponification
Saponification
(CH3CO)2O
C7H7SO3H
CH3OH
(CH3)2C(OCOCH3)-COCH2CH=CH2 (II)
CH3OH KOH
(CH3)2C(OH)-COCH2CH(OCH3)CH3 (VII)
CH3OH KOH
(CH3)2C(OCOCH3)-COCH=CHCH3 (III)
15% H2SO4
(CH3CO)2O
C7H7SO3H
CH3COOH Hg(OCOCH3)2
(CH3)2C(OH)-COCH2CH(OH)CH3 (IX)
(CH3)2C(OCOCH3)-COCH2CH(OCH3)CH3 (VIII)
(CH3)2C(OCOCH3)-COCH2CH(OCOCH3)CH3 (X)

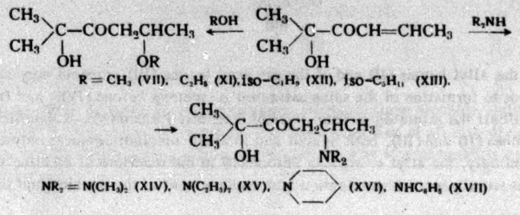
position. On heating the unsaturated α-acetoxy ketones (II) and (III) in methanol, in the presence of a catalytic amount of caustic potash or concentratred sulfuric acid, there is simultaneous re-esterification and union of methanol with the double bond, with formation of the same β-methoxy-α-ketole (VII) and equivalent amount of methyl acetate. By distilling the ketole (VII) in the presence of 1% p-toluenesulfonic acid methanol is quantitatively split off, and dimethylcrotonyl carbinol (VI) is formed with a yield of 95%.

With careful acetylation of the ketole (VII) with acetic anhydride its acetate (VIII) is obtained, the distillation of which in the presence of p-toluenesulfonic acid leads to the above-named unsaturated α-acetoxy ketone (III). The latter is obtained also by the action of acetic anhydride on α-keto-alcohol (VI). Hydrogenation of this latter (VI) in the presence of a Pt catalyst produces the above-named saturated keto-alcohol (V).

Hydrolysis of the unsaturated α-acetoxy ketones (II) and (III), or of the β-methoxy-α-ketole (VII), with the aid of 15% sulfuric acid, leads to formation of the ketodiole (IX) together with the unsaturated α-ketole (VI). The diacetate of this ketodiole (X) is formed with low yield (10%) by direct union of acetic acid to the α-acetoxy ketones (II) and (III) in the presence of mercuric acetate.

The double bond in the α-keto-alcohol (VI) as also in the α-acetoxy ketones (II and III), is distinguished by its high activity and easily enters into various addition reactions. The alcohols (methyl, ethyl, isobutyl, isoamyl), in the presence of catalytic amounts of alkali or sulfuric acid, are easily added to the unsaturated α-keto-alcohol (VI), forming in this way the corresponding β-alkoxy-α-keto-alcohols (VII, XI, XII- and XIII).

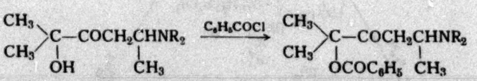
The amines (dimethylamine, diethylamine, piperidine, aniline) are also easily added to the α-keto-alcohol (VI), with formation of the corresponding β-amino-α-keto-alcohols (XIV-, XV, XVI and XVII).



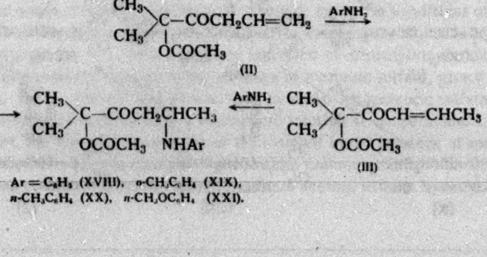
$R = CH_3$ (VII), C_2H_5 (XI), iso-C_4H_9 (XII), iso-C_5H_{11} (XIII).

$NR_2 = N(CH_3)_2$ (XIV), $N(C_2H_5)_2$ (XV), (XVI), NHC_6H_5 (XVII)

By the action of benzoyl chloride on the aminoketo alcohols (XIV to XVII) the corresponding benzoates are formed, which may be of interest for pharmacological research and in the further synthesis of physiologically active preparations



On boiling the α-acetoxy ketones (II and III) with aniline, o-toluidine, and p-anisidine in dioxan solution in the presence of water, the corresponding α-acetoxy-β-arylamino ketones (XVIII to XXI) are obtained

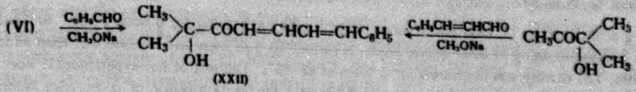


(II)

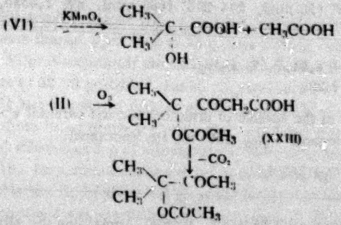
(III)

$Ar = C_6H_5$ (XVIII), o-$CH_3C_6H_4$ (XIX), n-$CH_3C_6H_4$ (XX), n-$CH_3OC_6H_4$ (XXI).

Dimethylcrotonyl carbinol (VI) is a vinylog of dimethylacetyl carbinol, easily condensed with aromatic aldehydes. On condensing this carbinol (VI) with benzaldehyde in the presence of sodium methylate the ketodienol (XXII) is formed, obtained earlier by Scheibler and Fischer [5] by condensing dimethyl carbinol with cinnamic aldehyde.



The structure of the dimethylcrotonyl carbinol (VI) and of its acetate (III), as also of the acetoxy ketone (II) was confirmed by oxidation and ozonization.



On oxidizing the propenyl α-keto-alcohol (VI) or its acetate (III) with potassium permanganate, acetic acid and α-hydroxyisobutyric acid or its acetate were obtained. In ozonizing the allyl α-acetoxy ketone (II), as was to be expected, formic acid and β-keto acid (XXIII) were formed; and this latter was decarboxylated to produce the acetate of dimethylacetyl carbinol. However, with this also is formed α-hydroxyisobutyryl acetate, indicating the partial isomerization of the allyl α-acetoxy ketone (II) into the propenyl α-acetoxy ketone (III) during ozonization. Oxidation with permanganate of the allyl acetoxy ketone (II) is accompanied by the almost complete isomerization into propenyl α-acetohydroxy ketone (III), and therefore the expected acetate of the dimethylacetyl carbinol is formed in such case in negligible amount.

EXPERIMENTAL

Acetylation of dimethylvinylethinyl carbinol. 570 g of this substance was added dropwise for 5 hours to a mixture of 570 g acetic anhydride and 15 g anhydrous zinc chloride, with vigorous stirring. Temperature of the reacting mixture was kept at 20-25° by cooling with ice-water and rate of feed of carbinol. After all the carbinol had been added the reaction mixture was stirred at room temperature for a further 3 hours. On the following day the product formed was treated with a saturated solution of kitchen salt, the oily layer formed was separated, neutralized with soda, dried with calcium chloride, and twice distilled in vacuum. Yield was 672 g of dimethylvinylethinyl carbinol acetate (I), of b.p. 62-64° (10 mm), n_D^{20} 1.4630 [6].

Hydration of dimethylvinylethinyl carbinol acetate. a) A solution of 5 g mercuric acetate in 150 g of 85% acetic acid was poured into a three-necked flask fitted with mechanical stirrer, thermometer, and drop funnel, and 100 g of the acetate (I) was added dropwise for 4 hours at 40°. A slight evolution of heat was therby observed. A further 3 g of mercuric acetate was then added to the reaction mixture, and stirring at 40-45° renewed for another 3 hrs. The dark-colored product was decanted from the separated mercury, the acetic acid distilled in vacuum over the water-bath at 40-50°, and the residue distilled in vacuum with oil pump (2-4 mm). The residue in the flask comprised 25 g of resinous substance. After repeated distillation 75 g was obtained of the acetate of dimethyl-(vinylacetyl) carbinol (II) in the form of a colorless liquid with a fairly agreeable smell.

B.p. 68-69° (4 mm) 84-86° (10 mm), n_D^{20} 1.4455, d_4^{20} 1.0018, MR 45.26; calc. 44.96.

Found %: C 63.61, 63.67; H 8.58, 8.72. $C_9H_{14}O_3$.
Calculated %: C 63.53; H 8.29.

The 2,4-dinitrophenylhydrazone of the acetate of dimethyl-(vinylacetyl) carbinol comprises yellow crystals of m.p. 121-122° (from alcohol), λ_{max} 345 mμ (in isooctane).

Found %: N 16.08, 15.88. $C_{15}H_{18}O_6N_4$.
Calculated %: N 15.99.

b) 240 g of the acetate (I) was added dropwise with constant stirring for 6 hours at 60° to a solution of 15 g mercuric acetate in 450 g of 90% acetic acid. A further 10 g of mercuric acetate was then added to the reaction mixture, and stirring was continued for 6 hours at 65-80°. The rest of the experimental work was the same as before. As a result 188 g was obtained of a difficultly separable mixture of α-acetoxy ketones (II) and (III) of b.p. 82-98° (10 mm), n_D^{20} 1.4495. By fractional distillation first in vacuum and then under atmospheric pressure 85 g of the acetate of dimethylcrotonyl carbinol (III), was separated as a colorless liquid with a sharp taste.

B.p. 77-78° (4 mm), 93-95° (10 mm), 204-206° (680 mm), n_D^{20} 1.4545, d_4^{20} 1.0066, MR 45.83; calc. 44.96.

Found %: C 63.80, 63.69; H 8.41, 8.52. $C_9H_{14}O_3$.
Calculated %: C 63.53; H 8.29.

2,4-Dinitrophenylhydrazone of the acetate of dimethylcrotonyl carbinol was in the form of orange-colored crystals of m.p. 132-133° (from alcohol) λ_{max} 350 mμ (in isooctane).

Found %: N 16.05, 15.69. $C_{15}H_{18}O_6N_4$.
Calculated %: N 15.99.

All the first fractions to the extent of 98 g (n_D^{20} 1.4505) containing the allyl ketone (II) were combined and heated at 45-55° with a solution of 2 g sulfuric acid in 200 g dioxan with stirring for 6 hours. The dioxan was distilled off in vacuum, the residue treated with aqueous soda solution and extracted with ether. When distilled a further 90 g was obtained of the propenyl α-acetoxy ketone (III) of b.p. 93-95° (10 mm) n_D^{20} 1.4550, of which the 2,4-dinitrophenylhydrazone melted at 131-132° and showed no depression with the above-described sample.

Hydration of acetate (I) at a higher temperature (up to 80-95°) led for the most part to the production of the propenyl α-acetoxy ketone (III) with admixture of the addition product of acetic acid with β-β-dimethyldivinyl ketone, formed under the reaction conditions in saponifying the original acetate (I) with subsequent isomerization [7].

Isomerization of the allyl acetoxy ketone (II) to the propenyl acetoxy ketone (III). a) A mixture of 12 g of the allyl ketone (II) (b.p. 84-86° under 10 mm, n_D^{20} 1.4455), 25 g acetic acid, and 1.2 g mercuric acetate was boiled with reflux condensing for 6 hours. On distilling the reaction mixture in vacuum 10.8 g was obtained of the propenyl ketone (III), of b.p. 93-95° (10 mm) n_D^{20} 1.4550. Its 2,4-dinitrophenylhydrazone had m.p. 131-133°, without depression on mixing with the above-described sample.

b) A mixture of 12.5 g of allyl ketone (II), 25 g acetic acid, and 2 g sodium acetate, was boiled with reflux condensing for 7 hours. On distilling the reaction mixture in vacuum 11 g was obtained of the propenyl ketone (III) of b.p. 94-95° (10 mm) n_D^{20} 1.4552. Its dinitrophenylhydrazone melted at 131-132°.

c) A mixture of 45 g allyl ketone (II), 90 g acetic acid, and 2 g mercuric sulfate was shaken up at 40-60° for 4 hours. After distilling off the acetic acid in vacuum over the water bath (35-45°) the residue was treated with soda, extracted with ether, dried with magnesium sulfate, and distilled in vacuum. 38 g was obtained of the propenyl ketone (III) of b.p. 93-95° (10 mm) n_D^{20} 1.4550. The 2,4-dinitrophenylhydrazone melted at 132-133° and showed no depression with the above-described sample.

d) A mixture of 25 g of the allyl ketone (II) and 50 g dioxan containing 0.5 g concentrated sulfuric acid, was shaken up at 45-55° for 5 hours. After treatment as before 21.5 g was obtained of the propenyl ketone (III) of b.p. 93-94° (10 mm) n_D^{20} 1.4550. The 2,4-dinitrophenylhydrazone melted at 131-133°.

e) 5 g of the allyl ketone (II) (b.p. 68-69° under 4 mm, n_D^{20} 1.4455) was distilled with 0.15 g p-toluenesulfonic acid in vacuum (4 mm). 4 g was obtained of the propenyl ketone (III) of b.p. 77-78° (4 mm); n_D^{20} 1.4545. The 2,4-dinitrophenylhydrazone melted at 131-133°, without depression.

Oxidation of the acetate of dimethylcrotonyl carbinol (III). 25 g of finely ground potassium permanganate was added to a mixture of 10.5g of this acetate of (III) with 175 ml water, with vigorous stirring and cooling with ice-water. On the following day the precipitated manganese dioxide was squeezed out and washed with 50 ml hot water. The water was distilled from the filtrate in vacuum over the water bath at 30-40°; the residue after acidifying with concentrated hydrochloric acid (with vigorous gas formation) was carfully extracted with ether, and the extract dried with magnesium sulfate. On distilling the ether extract 2.1 g of acetic acid was obtained of b.p. 103-108° (formic acid, by the calomel test, was absent), together with 5.8 g of the α-hydroxyisobutyric acetate of b.p. 99-100° (3 mm) and 119-120° (10 mm), n^{20}_D 1.4285, which, on standing in the vacuum desiccator, crystallized and melted at 55-60° [8]. A solution of 7 g caustic soda in 20 ml water was added with cooling to the α-hydroxyisobutyric acetate. After heating on the water bath for 3 hrs at 50-70° the mixture was acidified with concentrated hydrochloric acid, carefully extracted with ether, and the product dried with magnesium sulfate. After distilling off the ether the residue in the flask was crystallized. 3 g of hydroxyisobutyric acid was obtained of m.p. 78-79° (from benzene) without depression by the usual test [8].

Ozonization of the allyl acetoxy ketone (II). Ozonized oxygen (ozone concentration 4.5%) was passed at the rate of 20 liters/hr for 8 hours through a solution of 15 g allyl acetoxy ketone (II) in 85 g carbon tetrachloride, with cooling down to -10°. After distilling off the solvent under vacuum over the water bath (30°), the residue was shaken up with a mixture of 10 ml perhydrol and 45 ml water at 50-70° for 6 hours; after which 5 ml of dilute hydrochloric acid (1:1) was added and shaking up continued at 30-40° for a further 2 hours. The product was neutralized with soda, three times extracted with ether, and dried with magnesium sulfate. On distilling the etheric extract of neutral substances 5 g of the acetate of dimethylacetyl carbinol was obtained, of b.p. 60-63° (10 mm), n^{20}_D 1.4215. Its semicarbazone melted at 155-156°, and showed no depression by usual test. [9]. The residue in the distillation flask (about 1.5 g) could not be distilled owing to decomposition. The acetate of dimethylacetyl carbinol obtained was saponified in dimethylacetyl carbinol (b.p.134-136° (673mm), n^{20}_D 1.4160). Its semicarbazone melted at 164-165°, and showed no depression with a known sample [9]. The residue of salts obtained after distilling in vacuum the water and neutral products, was acidified with concentrated hydrochloric acid, and the acids carefully extracted with ether. On distilling, 1.6 g of a mixture of acetic and formic acids was obtained, of b.p. 95-105°, in which the formic acid was detected by the calomel method. Also 1.8 g of the acetate of α-hydroxyisobutyric acid was obtained, of b.p. 119-120° (10 mm), n^{20}_D 1.4290.

Hydrogenation of the allyl acetoxy ketone (II). 7 g of the allyl ketone (II) was hydrogenated in a solution of 14 g alcohol with a Pt catalyst. 1100 ml of hydrogen was absorbed (18°, 680 mm) instead of the 1124 ml required by theory for each double bond. The alcohol was distilled off in vacuum. On distilling the product 6.2 g of the acetate of dimethylbutyryl carbinol (IV) was obtained in the form of a mobile liquid with fruity smell.

B.p. 80-81° (19 mm) n^{20}_D 1.4300, d^{20}_4 0.9736, MR 45.59; calc. 45.42.

Found %: C 62.44, 62.90; H 9.64, 9.57. $C_9H_{16}O_3$.
Calculated %: C 62.77; H 9.36.

The semicarbazone of this acetate melted at 137-139° (from alcohol).

Found %: N 18.18. $C_{10}H_{19}O_4N_3$.
Calculated %: N 18.33.

Hydrogenation of the acetate of dimethylcrotonyl carbinol (III). 22.3 g of the propenyl ketone (III) in a solution of 40 ml alcohol was hydrogenated with Pt catalyst. Total absorption 3.5 liters hydrogen (18°, 680 mm) instead of the 3.58 liters required theoretically. By distillation in vacuum 20.5 g of the above-described dimethylbutyryl carbinol (IV) was obtained, of b.p. 79-81° (9 mm). Its semicarbazone melted at 138-139°, without depression by the known test.

Saponification of the acetate of dimethylbutyryl carbinol (IV). 8 g of this acetate (IV) was gradually added with stirring and cooling to a solution of 2.7 g caustic potash in 25 g of 90% methanol. After heating over the water bath for 2 hours the methanol was driven off under vacuum, the residue diluted with water, dried with potash, and the product extracted with ether, dried with magnesium sulfate, and distilled. 5.5 g of dimethylbutyryl carbinol (V) was obtained as a colorless liquid with agreeable smell.

B.p. 58.60° (10 mm), 163-165° (680mm), n^{20}_D 1.4265, d^{20}_4 0.9237, MR 36.15; calc. 36.06.

Found %: C 64.58, 64.38; H 10.78, 11.03. $C_7H_{14}O_2$.
Calculated %: C 64.61; H 10.76.

The semicarbazone of the product, after twice recrystallizing from alcohol, melted at 140-142°.

Found %: N 23.07, 22.97. $C_8H_{17}O_2N_3$.
Calculated %: N 22.46.

Re-esterification of the acetate of dimethylcrotonyl carbinol (III). 120 g of this acetate of (III) was added dropwise to a solution of 6 g powdered caustic potash in 360 ml methanol with stirring for 2 hours; in which a small evolution of heat was noted. Then the reaction mixture was boiled over the water-bath for 8 hrs, the methanol and methylacetate distilled under a low vacuum, the residue diluted with water, saturated with potash, extracted with ether, and dried with magnesium sulfate. After distilling off the ether the product was redistilled in vacuum. 105 g was obtained of dimethyl-β-methoxybutyryl carbinol (VII) as a colorless liquid of agreeable smell.

B.p. 82-83° (10 mm), n^{20}_D 1.4365, d^{20}_4 0.9810, MR 42.73; calc. 42.32.

Found %: C 59.67, 60.04. H 10.67, 10.28. $C_8H_{16}O_3$.
Calculated %: C 59.97; H 10.06.

The semicarbazone of the methoxy ketone (VII) melted at 137-138° (from alcohol).

Found %: N 19.50. $C_9H_{19}O_3N_3$.
Calculated : %: N 19.49.

Re-esterification of the acetate of dimethyl-(vinylacetyl) carbinol (II). 10 g of the acetate (II) was gradually added with stirring to a mixture of 35 g methanol and 0.5 g of powdered caustic potash. The reaction mixture was boiled over the water bath for 5 hours. After proceeding as before 8.6 g dimethyl-β-methoxybutyryl carbinol (VII) was obtained, of b.p. 85-86° (11 mm), n^{20}_D 1.4360. The semicarbazone melted at 137-138°, without depression under usual test.

A similar re-esterification of the acetoxy ketones (II and III) was effected also in the presence of a few drops of concentrated sulfuric acid.

Splitting off methanol from the dimethyl-β-methoxybutyryl carbinol (VII). 50 g of this carbinol (VII) was heated for 1 1/2 hour in vacuum (90 mm) in the presence of 0.5 g p-toluenesulfonic acid. The methanol split -off began at a water bath temperature of 70-90°. After distilling the methanol (8 g) the residue was distilled under an oil-pump vacuum of 2-3 mm. From subsequent distillation of the product under vacuum 38.5 g of the dimethylcrotonyl carbinol (VI) was obtained as colorless liquid of pungent odor.

B.p. 66-68° (10 mm), 175-178° (680mm), n^{20}_D 1.4590, d^{20}_4 0.9660, MR 36.26; calc. 35.58.

Found %: C 65.23, 65.41; H 9.38, 9.34; OH 14.10. $C_7H_{12}O_2$.
Calculated %: C 65.59; H 9.43; OH 13.28.

Bromine to saturation point was added to a solution of 5 g of product (VI) in 15 g carbon tetrachloride with cooling and stirring. The product was distilled in vacuum and 8 g of the dibromide was obtained.

B.p. 92-93° (2 mm); n^{20}_D 1.5150, d^{20}_4 1.6547, MR 52.46; calc. 51.60.

Found %: Br 54.84, 54.60. $C_7H_{12}O_2Br_2$.
Calculated %: Br 55.50.

Oxidation of the dimethylcrotonyl carbinol (VI). 33 g of finely pulverized permanganate of potash was added to a mixture of 10 g of this carbinol (VI) and 200 ml water with vigorous stirring and cooling with water in small portions. The product was treated in the same way as in the oxidation of its acetate (III). After driving off the ether and low boiling substances under vacuum (10 mm) the residue was crystallized. From repeated distillation under atmospheric pressure 2.5 g of acetic acid was collected, of b.p. 102-108°. the calomel test for formic acid gave a negative result. The remaining crystalline residue in the distillation flask was re-distilled from benzene and acetone. 5 g of α-hydroxyisobutyric acid was obtained of m.p. 77-79° [8].

Acetylation of the dimethyl-β-methoxybutyryl carbinol (VII). 7 g of this carbinol (VII) was gradually added, with water-cooling, to 7 g of acetic anhydride containing a drop of concentrated sulfuric acid. On the following day the product was diluted with water, neutralized with soda, extracted with ether. dried with magnesium sulfate, and distilled in vacuum. 6.8 g of the acetate of dimethyl-β-methoxybutyryl carbinol (VIII) was obtained.

B.p. 98-100° (9 mm), n^{20}_D 1.4360, d^{20}_4 1.0133, MR 52.17; calc. 51.68.

Found %: C 59.38; H 9.38. $C_{10}H_{18}O_4$.
Calculated %: C 59.39; H 8.97.

Splitting off methanol from the acetate of dimethyl-β-methoxybutyryl carbinol (VIII). 4.5 g of the acetate of (VIII) was heated with a catalytic amount (about 0.04 g) of p-toluenesulfonic acid over the boiling water bath under vacuum (100 mm) for 2 hours. The product was treated with soda, extracted with ether, dried with magnesium sulfate, and distilled in vacuum. 3 g of the acetate (III) was obtained, of b.p.91° (9 mm), n^{15}_D 1.4550. Its 2,4-dinitrophenylcarbazone melted at 131-133°, without depression under usual test.

Acetylation of the dimethylcrotonyl carbinol (VI). 13.5 g of carbinol (VI) was gradually added with cooling to 15 g acetic anhydride containing 2 drops concentrated sulfuric acid. The reaction mixture was heated over the water bath for 1 hour. 14.5 g of the acetate of dimethylcrotonyl carbinol (III) was obtained in the usual way, of b.p. 85-86° (7 mm), n^{22}_D 1.4535. Its 2,4-dinitrophenylhydrazone melted at 130-132°, and showed no depression with the above-described sample.

Hydrogenation of dimethylcrotonyl carbinol (VI). 4.3 g of the carbinol (VI) was hydrogenated in solution in 15 ml alcohol with a Pt catalyst. The theoretical amount of hydrogen required for one double bond was absorbed. 4 g of dimethylbutyryl carbinol (V) was obtained of b.p. 163-165° (680 mm), n^{20}_D 1.4265. The semicarbazone melted at 140-141°, and showed no depression with the known sample.

Hydrolysis of dimethyl-β-methoxybutyryl carbinol (VII) A mixture of 17 g of the methoxyketole (VII) with 80 g of 15% sulfuric acid, under vigorous stirring, was heated at 50-70° for 17 hours. The product was saturated with potash, extracted with ether, and after drying with magnesium sulfate, was distilled in vacuum. 4 g was obtained of dimethylcrotonyl carbinol (VI) (b.p. 66-68°, with n^{20}_D of 1.4590), together with 10 g dimethyl-β-hydroxybutyryl carbinol (IX) as a colorless thick liquid.

B.p. 83° (1 mm), 113-115° (10 mm), n^{20}_4 1.4515, d^{20}_4 1.0468, MR 37.64; calc. 37.58.

Found %: C 57.77, 57.63; H 9.65, 9.87. $C_7H_{14}O_3$.
Calculated %: C 57.51; H 9.61.

Hydrolysis and Saponification of the acetate of dimethyl-(vinylacetyl) carbinol (II). a) A mixture of 30 g allyl-α-acetoxy ketone (II) and 100 g of 10% sulfuric acid was vigorously stirred over a boiling water-bath till the oily layer was dissolved. The products of hydrolysis were treated as before. 16 g of dimethylcrotonyl carbinol (VI) was obtained (b.p. 65-67° under 10 mm, n^{20}_D 1.4580) together with 3 g dimethyl-β-hydroxybutyryl carbinol (IX) b.p. 112-114° (10 mm), n^{20}_D 1.4520.

b) A mixture of 36 g allyl-α-acetoxy ketone (II) and 100 g of 15% potash solution were heated, with vigorous stirring, on the boiling water bath for 3 hours. The product was saturated with potash, extracted with ether, and, after drying, was distilled in vacuum. 13.5 g of dimethylcrotonyl carbinol (VI) was obtained (b.p. 64-67° under 10 mm, n^{20}_D 1.4578), and 7 g of the propenyl-α-acetoxy ketone (III) (b.p.93-96° under 10 mm, n^{20}_D 1.4550).

Similar results were obtained with acid hydrolysis and alkaline saponification of the acetate of dimethylcrotonyl carbinol (III).

Addition of acetic acid to the acetate of dimethylcrotonyl carbinol (III). A mixture of 20 g propenyl α-acetoxy ketone (III), 60 g glacial acetic acid, and 10 g mercuric acetate was boiled with reflux condensing for 20 hours. The reaction mixture, after separation of the mercury, was twice distilled in vacuum. 13 g of the initial α-acetoxy ketone (III) was obtained, together with 2.2 g diacetate (X).

B.p. 102-103° (2 mm), n^{20}_D 1.4390, d^{20}_4 1.0723, MR 56.46; calc. 56.31.

Found % : C 57.04, 57.37; H 7.93, 8.05. $C_{11}H_{18}O_5$.
Calculated %: C 57.39; H 7.82.

Condensation of the dimethylcrotonyl carbinol (VI) with benzaldehyde. 10 ml sodium methylate, prepared by dissolving 5 g metallic sodium in 100 ml methanol, was added to a mixture of 12 g of the carbinol (VI), 12 g of freshly distilled benzaldehyde and 50 ml alcohol. On the following day the reaction mass was heated over the water bath at 50-60° for 2 hours. The alcohol was removed under vacuum, the residue treated with water, extracted with ether, and dried with magnesium sulfate. After distilling off the ether the crystalline residue was dissolved in benzene and again precipitated with petroleum ether. 14 g of 2-methyl-7-phenyl-3,6-heptadiene-2-ole-3-one (XXII) was obtained, of m.p. 108-110° [5].

Found %: C 77.82, 78.01; H 7.69, 7.49. $C_{14}H_{16}O_2$.
Calculated %: C 77.77; H 7.40.

Addition of alcohols to dimethylcrotonyl carbinol (VI). a) A mixture of 20 g α-keto-alcohol (VI) and 100 ml methanol, containing 2 drops of concentrated sulfuric acid, was boiled with reflux condensing for 5 hrs. The methanol was distilled off in vacuum, the residue treated with potash solution, extracted with ether, and after drying distilled in vacuum. 21 g of the above-described dimethyl-β-methoxybutyryl carbinol (VII) was obtained, of b.p. 91-92° (14 mm), n_D^{20} 1.4365. The semicarbazone melted at 137-138°.

b) 10 g of the carbinol (VI) was added dropwise with stirring to 50 g ethanol containing 0.15 g caustic potash. The reaction mixture was heated over the water-bath at 40-50° for 6 hrs. After treatment as before 8 g of dimethyl-β-ethoxybutyryl carbinol (XI) was obtained.

B.p. 90-92° (11 mm), n_D^{20} 1.4315, d_4^{20} 0.9534, MR 47.32; calc. 46.93.

Found %: C 61.92, 62.15; H 9.15, 9.38. $C_9H_{18}O_3$.
Calculated %: C 62.05; H 9.25.

The semicarbazone melted at 123-125° (from alcohol).

Found %: N 18.02, $C_{10}H_{11}O_3N_3$.
Calculated %: N 18.17.

c) 10 g of the carbinol (VI) was added with stirring to a solution of 0.2 g metallic sodium in 50 g isobutyl alcohol. The work proceeded as before. As a result 8.5 g dimethyl-β-isobutoxybutyryl carbinol (XII) was obtained.

B.p. 101-102° (8 mm), n_D^{20} 1.4335, d_4^{20} 0.9285, MR 56.68; calc. 56.18.

Found %: C 65.39, 65.27; H 11.13, 11.43. $C_{11}H_{22}O_3$.
Calculated %: C 65.31. H 10.96.

The semicarbazone melted at 116-117° (from alcohol).

Found %: N 16.41, 16.76. $C_{12}H_{25}O_3N_3$.
Calculated %: N 16.20.

d) 10 g of the ketoalcohol (VI) was added at room temperature and with stirring to 50 g isoamyl alcohol containing 0.1 g caustic potash. After the usual treatment, 9 g of dimethyl-β-isoamyloxybutyryl carbinol (XIII) was obtained.

B.p. 90 - 92° (2 mm), n_D^{20} 1.4355, d_4^{20} 0.9238, MR 61.18; calc. 60.79.

Found %: C 66.08, 66.29; H 11.31, 11.16. $C_{12}H_{25}O_3$.

Calculated %: C 66.67; H 11.18.

The semicarbazone melted at 94-95° (from alcohol).

Found %: N 15.78, 15.73. $C_{13}H_{27}O_3N_3$.

Calculated %: N 15.37.

Addition of amines to dimethylcrotonyl carbinol (VI) and acetates (II) and (III). a) 5 g of the carbinol (VI) was gradually added with water-cooling to 10 ml of 32% aqueous dimethylamine. On the following day, excess dimethylamine was distilled off in vacuum at 30-40°. The residue was saturated with potash, extracted with ether and dried with magnesium sulfate. After passing dry hydrogen chloride into the ether solution 7.1 g of the hydrochloride of dimethyl-β-dimethylaminobutyryl carbinol (XIV) was obtained, of m.p. 111-112° (precipitated from alcoholic solution).

Found %: N 6.67, 6.41. $C_9H_{20}O_2NCl$.
Calculated %: N 6.68.

The oxalate of substance (XIV), after recrystallizing from alcohol, melted at 107-108°.

Found %: N 5.11, 5.33. $C_{11}H_{21}O_6N$.
Calculated %: N 5.32.

On heating 4 g of the hydrochloride of the amino ketoalcohol (XIV) with 6 g benzoyl chloride over the metal bath at 110-130°, until separation of hydrogen chloride has stopped, and subsequent treatment of the reaction mass with ether and acetone, 2.5 g of the hydrochloride of dimethyl-β-dimethylaminobutyryl carbinol benzoate separated, of m.p. 98-100°.

Found %: N 4.43. $C_{16}H_{24}O_3NCl$.
Calculated %: N 4.4.

b) 0.75 g diethylamine was added to 1.3 g dimethylcrotonyl carbinol (VI), and the mixture heated over the water bath to 30-50° for 30 min. The product was diluted with absolute ether, and dry hydrogen chloride was passed into the ether solution. 2 g of the hydrochloride of dimethyl-β-diethylaminobutyryl carbinol (XV) was obtained, of m.p. 141-143° (from anhydrous alcohol).

Found %: N 5.91, 6.12. $C_{11}H_{24}O_2NCl$.
Calculated %: N 5.89.

c) In a similar way by the action of 0.85 g piperidine on 1.3 g of the α-ketoalcohol (VI), 2.1 g of the hydrochloride of dimethyl-β-piperidylbutyryl carbinol (XVI) was obtained, of m.p. 148-149° (from anhydrous alcohol).

Found %: N 5.70, 5.65. $C_{12}H_{24}O_2NCl$.
Calculated %: N 5.61.

d) A mixture of 14 g α-keto alcohol (VI), 18 g aniline, 6 g water, and 15 g dioxan was boiled with reflux condensing for 12 hrs. After distilling the product in vacuum 13 g of dimethyl-β-phenylaminobutyryl carbinol (XVII) was obtained as a thick colorless oil of b.p. 136-138° (1.5 mm), n_D^{20} 1.5400.

Found %: C 70.67; H 8.48. $C_{13}H_{19}O_2N$.
Calculated %: C 70.58; H 8.65.

The hydrochloride melted at 138-139° (from mixed acetone and alcohol).

Found %: N 5.45, 5.68. $C_{13}H_{20}O_2NCl$.
Calculated %: N 5.43.

e) A mixture of 30 g of the acetate (III), 30 g aniline, 6 ml water, and 40 ml alcohol was boiled with reflux condensing for 20 hours. On distilling in vacuum 35 g of the acetate of dimethyl-β-phenylaminobutyryl carbinol (XVIII) was obtained, of b.p. 148-150° (2 mm), which crystallized in the receiver, and melted at 45-46° (from aqueous alcohol or petroleum ether).

Found %: C 68.27, 68.25; H 8.02, 7.72. $C_{15}H_{21}O_3N$.
Calculated %: C 68.42; H 8.03.

The hydrochloride melted at 136-137° (from alcohol).

f) In a similar way by boiling a mixture of 15 g of the allyl acetoxy ketone (II), 20 g aniline, 5 ml water, and 30 ml ethanol, 18 g of the acetate of dimethyl-β-phenylaminobutyryl carbinol (XVIII) was obtained, of m.p. 45-46°, without depression with the preceding sample.

g) By boiling a mixture of 9 g of the propenyl α-acetoxy ketone (III), 6 g p-toluidine, 1.5 ml water, and 10 ml dioxan, 10 g of the acetate of dimethyl-β-(p-tolylamino)-butyryl carbinol (XX) was obtained, of b.p. 145-148° (0.5 mm), m.p. 55-56° (from petroleum ether).

Found %: N 5.11, 5.16. $C_{16}H_{23}O_3N$.
Calculated %: N 5.05.

The hydrochloride melted at 149-151° (from mixed alcohol and acetone).

Found %: N 5.07, 4.90. $C_{16}H_{24}O_3NCl$.
Calculated %: N 4.46.

h) On boiling a mixture of 10 g of the allyl α-acetoxy ketone (II), 9 g o-toluidine, 2 ml water, and 12 ml dioxan for 12 hrs. 9 g of the acetate of dimethyl-β-(o-tolylamino)-butyryl carbinol (XIX) was obtained, of b.p. 145-147° (1 mm), m.p. 51-52.5° (from petroleum ether).

Found %: N 5.26. $C_{16}H_{23}O_3N$.
Calculated %: N 5.05.

The hydrochloride melted at 126-127° (from acetone).

Found %: N 4.85. $C_{16}H_{24}O_3NCl$.
Calculated %: N 4.46.

j) On boiling a mixture of 9 g of the α-acetoxy ketone (III), 6 g p-anisidine, 1.5 ml water, and 10 ml dioxane for 10 hours, 8 g of the acetate of dimethyl-β-(p-methoxyphenylamino)-butyryl carbinol (XXI) was obtained, of b.p. 158-163° (1 mm), m.p. 96.5-98° (from petroleum ether).

Found %: N 5.16. $C_{16}H_{23}O_4N$.
Calculated %: N 4.78.

The hydrochloride had m.p.148-150° (from mixed acetone and alcohol).

Found %: N 4.54. $C_{16}H_{24}O_4NCl$.
Calculated %: N 4.24.

The addition products of amines of the aliphatic series to α-keto-alcohol or to α-acetoxy ketones (II) and (III), when distilled, undergo partial splitting; whereas the analogous addition products with aromatic amines can be distilled without decomposition, and their splitting takes place on heating with acids. This difference is explained by the much weaker basic properties of the aromatic amines.

Splitting of β-arylamino-α-keto-alcohols. a) A solution of 2 g dimethyl-β-phenylaminobutyryl carbinol (XVII) in 10 ml concentrated hydrochloric acid was boiled for $1\frac{1}{2}$ hour. After distilling off the water and neutral substances the crystalline residue melted at 199-200°, and showed no depression with aniline hydrochloride.

b) Similarly by boiling a solution of 0.7 g β-amino ketone (XX) in 4 ml concentrated hydrochloric acid the p-toluidine hydrochloride was obtained, from which the base was separated, of m.p. 43-45°.

SUMMARY

1. It has been shown that the acetate of dimethylvinylethinyl carbinol in acetic acid solution, in the presence of mercuric acetate at 40-45°, is hydrated into the acetate of dimethyl-(vinylacetyl) carbinol, with a yield of about 70%.

2. It has been established that the acetate of dimethyl-(vinylacetyl) carbinol, under hydration conditions at a raised temperature (60-75°), or in the presence of acid or alkaline reagents, is easily isomerized into the acetate of dimethylcrotonyl carbinol.

3. A series of conversions of unsaturated α-acetoxy ketones has been studied; and more especially the high activity of their double bond for addition reactions has been indicated.

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[9] I. N. Nazarov, Bull. Acad. Sci. USSR. Div. Chem. Sci. 1940, 198 and 220.

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ACETYLENE DERIVATIVES

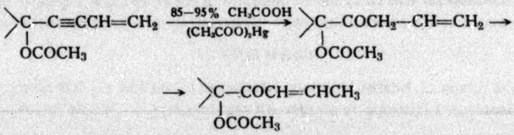
186. HYDRATION OF THE ACETATES OF TERTIARY VINYLETHINYL CARBINOLS SYNTHESIS AND CONVERSION OF UNSATURATED α-ACETOXY KETONES

I.N. Nazarov and S.G. Matsoyan

In a previous communication it was shown that the acetate of dimethylvinylethinyl carbinol, in acetic acid solution in the presence of mercuric acetate at 40-45°, is easily hydrated, forming the acetate of dimethylvinylacetyl carbinol, which, at a raised temperature under the conditions of hydration, or in the presence of acid and alkaline reagents, is isomerized into the acetate of dimethylcrotonyl carbinol [1]. Owing to the presence of functional groups and a double bond distinguished for high activity, the unsaturated α-acetoxy ketones are of great synthetic interest.

With a view to further extending this reaction and to studying the conversions of unsaturated α-acetoxy ketones, in the present work the hydration of three new acetates of tertiary vinylethinyl carbinols is undertaken. As was to be expected the hydration at a temperature of 40-50° of the acetates of methylethyl-and of methyl-n-propyl-vinylethinyl carbinols, as also the acetate of 1-vinylethinylcyclohexanol in 85-95% acetic acid solutions in the presence of mercuric acetate, leads to formation with good yields of the corresponding allyl α-acetoxy ketones.

These latter so obtained, by boiling in acetic acid solution in the presence of mercuric acetate, and also under the action of acid and alkaline reagents, are easily isomerized into the corresponding and more stable propenyl α-acetoxy ketones with the conjugated system of the carbonyl group and double bond.

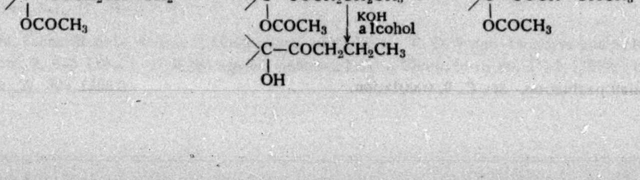


$$\underset{OCOCH_3}{>C}-C\equiv CCH=CH_2 \xrightarrow[(CH_3COO)_2Hg]{85-95\%\ CH_3COOH} \underset{OCOCH_3}{>C}-COCH_2-CH=CH_2 \rightarrow \underset{OCOCH_3}{>C}-COCH=CHCH_3$$

The constants of the unsaturated α-acetoxy ketones (III-VIII) are given in Table 1. For comparison the α-acetoxy ketones (I and II) described in a previous communication [1] are also given.

As can be seen from Table 1 the propenyl acetoxy ketones boil at 9-11° higher, have higher refractive indices, and greater density than the corresponding allyl acetoxy ketones. This state of affairs is observed also in the case of some known very complex allyl and propenyl ketones [2].

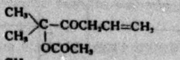
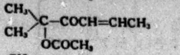
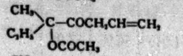
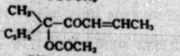
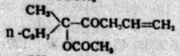
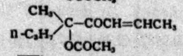
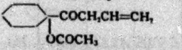
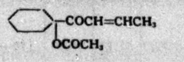
On hydrogenating the above-described allyl and propenyl α-acetoxy ketones with a Pt catalyst 1 M hydrogen is absorbed, and the saturated α-acetoxy ketones, conforming thereto, are thus formed, which, with alcoholic alkali, are easily saponified into the corresponding saturated α-keto-alcohols.



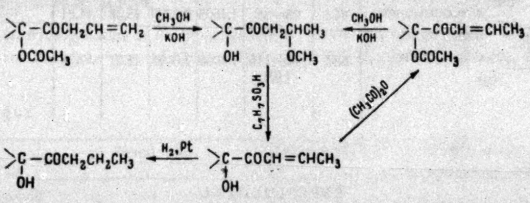
$$\underset{OCOCH_3}{>C}-COCH_2CH=CH_2 \xrightarrow{H_2,\ Pt} \underset{OCOCH_3}{>C}-COCH_2CH_2CH_3 \xleftarrow{H_2,\ Pt} \underset{OCOCH_3}{>C}-COCH=CHCH_3$$

$$\underset{OCOCH_3}{>C}-COCH_2CH_2CH_3 \xrightarrow{KOH\ alcohol} \underset{OH}{>C}-COCH_2CH_2CH_3$$

TABLE 1

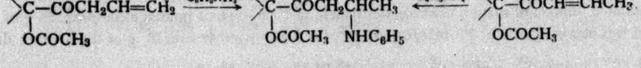
No.	Formula	Yield (%)	B.p. (10 mm)	n_D^{20}	d_4^{20}	MR_D found	MR_D calculated	Exaltation
(I)	 $\genfrac{}{}{0pt}{}{CH_3}{CH_3}{>}\underset{OCOCH_3}{C}-COCH_2CH=CH_2$	70	84—86°	1.4455	1.0018	45.26	44.96	0.3
(II)	 $\genfrac{}{}{0pt}{}{CH_3}{CH_3}{>}\underset{OCOCH_3}{C}-COCH=CHCH_3$	90	93—95	1.4545	1.0066	45.83		0.87
(III)	 $\genfrac{}{}{0pt}{}{CH_3}{C_2H_5}{>}\underset{OCOCH_3}{C}-COCH_2CH=CH_2$	68	95—97	1.4495	0.9937	49.77	49.57	0.4
(IV)	 $\genfrac{}{}{0pt}{}{CH_3}{C_2H_5}{>}\underset{OCOCH_3}{C}-COCH=CHCH_3$	83.5	105—107	1.4585	0.9992	50.35		0.78
(V)	 $\genfrac{}{}{0pt}{}{CH_3}{n\text{-}C_3H_7}{>}\underset{OCOCH_3}{C}-COCH_2CH=CH_2$	56.5	104—106	1.4515	0.9779	54.54	54.18	0.36
(VI)	 $\genfrac{}{}{0pt}{}{CH_3}{n\text{-}C_3H_7}{>}\underset{OCOCH_3}{C}-COCH=CHCH_3$	80	113—115	1.4600	0.9846	55.14		0.96
(VII)		61.5	130—132	1.4770	1.0453	56.82	56.61	0.21
(VIII)		80	139—141	1.4868	1.0435	57.59		0.98

On heating both the allyl and the propenyl α-acetoxy ketones in methanol in the presence of a small amount of caustic potash [1] the reactions proceed of addition of methanol through the double bond, and saponification of the acetoxy group (radical), leading to formation of the same β-methoxybutyryl carbinols.



The splitting off of methanol from these latter with the aid of p-toluenesulfonic acid gives with high yields the corresponding propenyl α-keto-alcohols; by acetylation of which with acetic anhydride in the presence of a trace of sulfuric acid the above-described α-acetoxy ketones are obtained. Through hydrogenation of the propenyl α-keto-alcohols with a Pt catalyst the above-mentioned saturated α-keto-alcohols are formed.

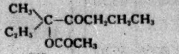
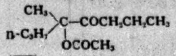
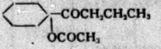
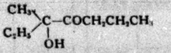
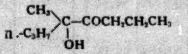
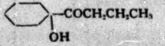
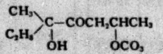
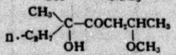
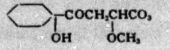
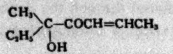
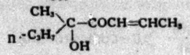
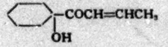
The allyl and propenyl α-acetoxy ketones, on heating with aniline in the presence of water, give high yields of the acetates of the corresponding β-phenylaminobutyryl carbinols



$$>\underset{OCOCH_3}{C}-COCH_2CH=CH_2 \xrightarrow{C_6H_5NH_2} >\underset{OCOCH_3}{C}-COCH_2\underset{NHC_6H_5}{CH}CH_3 \xleftarrow{C_6H_5NH_2} >\underset{OCOCH_3}{C}-COCH=CHCH_3$$

All the compounds obtained by the method described are given in Table 2.

TABLE 2

No.	Formula	Yield (%)	B.p. pressure (mm)	n_D^{20}	d_4^{20}	MR_D found	MR_D calculated	M.p. of semicarbazone
(IX)		91	92—93° (9)	1.4325	0.9691	49.88	50.04	—
(X)		92.5	101—103 (10)	1.4360	0.9561	54.75	54.65	—
(XI)		92	88—90 (1)	1.4605	1.0199	56.98	57.08	—
(XII)		87	69—70 (11)	1.4310	0.9173	40.70	40.67	118—120°
(XIII)		92.5	74—76 (10)	1.4330	0.9008	45.64	45.28	120—121
(XIV)		91	66—68	1.4650	0.9822	47.90	47.71	182—184
(XV)		94	90—92 (10)	1.4380	0.9705	47.37	46.93	151—152
(XVI)		84.5	99—101 (10)	1.4405	0.9597	51.73	51.54	146—148
(XVII)		86	127—128 (10)	1.4720	1.0254	54.67	53.98	166—168
(XVIII)		90	74—75 (10)	1.4595	0.9455	41.12	40.21	—
(XIX)		84.5	83—85 (10)	1.4605	0.9333	45.88	44.81	—
(XX)		83.5	114—116 (10)	1.4960	1.0193	48.21	47.25	—

EXPERIMENTAL

Acetate of methylethylvinylethinyl carbinol. 110 g of this carbinol was added dropwise and with stirring to a mixture of 120 g acetic anhydride and 2 g anhydrous zinc chloride for 4 hrs. The temperature of the reaction mixture was kept at 18-22° by cold-water cooling. Then the reaction mass was stirred at room temperature for 4 hours. On the following day a saturated solution of sodium chloride was added, the oily layer separating extracted with ether, neutralized with sodium bicarbonate, and dried with calcium chloride. By distillation 91 g was obtained of the acetate of the original carbinol, with b.p. 77-79° (10 mm), n_D^{18} 1.4665 [3].

Acetate of methyl-n-propylvinylethinyl carbinol. A mixture of 93 g of this carbinol with 100 g acetic anhydride and 3 g trichloroacetic acid was heated with stirring for 6 hours over the boiling water-bath. After cooling, a saturated solution of sodium chloride was added, and the product treated as before. 20 g of the original carbinol was obtained, of b.p. 73-74° (10 mm) n_D^{20} 1.4780, together with 68 g of the acetate therof.

B.p. 85-86° (9 mm), n_D^{20} 1.4660, d_4^{20} 0.9218, MR 54.15; calc. 52.18.

Found %: C 72.98, 72.69; H 8.98, 8.75. $C_{11}H_{16}O_2$.
Calculated %: C 73.31; H 8.95.

Acetate of 1-vinylethinylcyclohexanol-1 . A mixture of 80 g of the hexanol, with 120 g acetic anhydride and 2 g trichloroacetic acid was heated with stirring over the boiling water-bath for 5 hours. After treatment as before 78 g of the acetate was obtained, with b.p. 94-96°(3 mm), n^{23}_D 1.4950 [3].

Hydration of the acetate of methylethylvinylethinyl carbinol. 30 g of this acetate was added dropwise with stirring for 1 hour to a solution heated to 40° of 2 g of mercuric acetate in 70 g of 90% acetic acid. A further 1.5 g of mercuric acetate was added to the reaction mixture, after which stirring at 45-48° continued for 5 hours. Acetic acid was distilled off under vacuum at 40-45°, and from the residue, after repeated distillation, 22.5 g of the allyl acetoxy ketone (III) was obtained.

B.p. 95-97°(10 mm), n^{20}_D 1.4495, d^{20}_4 0.9937, MR 49.77; calc. 49.57.

Found %: C 65.16, 65.30; H 9.02, 9.13. $C_{10}H_{16}O_3$.
Calculated %: C 65.20; H 8.75.

Isomerization of the allyl acetoxy ketone (III) into the propenyl acetoxy ketone (IV). A mixture of 15 g of the allyl ketone (III), 50 g 70% acetic acid, and 3 g sodium acetate was boiled with reflux condensing for 6 hours. The acetic acid was distilled off in vacuum, the residue neutralized with soda, extracted with ether, and dried with magnesium sulfate. When distilled 12.5 g of the propenyl acetoxy ketone (IV) was obtained.

B. p. 105-107°(10 mm), n^{20}_D 1.4585, d^{20}_4 0.9992; MR 50.35; calc. 49.57.

Found %: C 65.40, 65.35; H 9.02, 8.95. $C_{10}H_{16}O_3$.
Calculated %: C 65.20; H 8.75.

The isomerization described proceeds also at temperature of 40 to 60° under the action of mercuric sulfate and sulfuric acid.

Acetate of methylethylbutyryl carbinol (IX). a) 6.5 g of the allyl ketone (III) in solution of 14 g alcohol was hydrogenated with a Pt catalyst. The theoretical amount of hydrogen required for one double bond was absorbed in 2 hours. On distillation in vacuum 6 g of the acetate (IX) was obtained.

B.p. 9-93°(9 mm), n^{20}_D 1.4325, d^{20}_4 0.9691, MR 49.88; calc. 50.04.

Found %: C 64.94, 64.75; H 10.17, 9.95. $C_{10}H_{18}O_3$.
Calculated %: C 64.50; H 9.74.

b) In similar hydrogenation of the propenyl ketone (IV) the theoretical amount of hydrogen was also easily absorbed, and the above-described acetate (IX) was formed of b.p. 57-58°(1 mm), 92-93°(9 mm), n^{20}_D 1.4325.

TABLE 3

No. of compound	Found (%)		Calculated (%)		Analysis of semicarbazones for nitrogen (%)	
	C	H	C	H	Found	Calculated
(V)	66.28, 66.35	9.46, 9.25	66.65	9.15	—	—
(VI)	66.43, 66.26	9.20, 9.32	66.65	9.15	—	—
(VII)	68.69, 68.61	9.04, 8.98	68.56	8.63	—	—
(VIII)	68.74, 68.60	9.06, 9.02	68.56	8.63	—	—
(X)	65.92, 65.90	10.29, 10.25	65.98	10.07	—	—
(XI)	68.14, 68.10	10.16, 9.93	67.91	9.49	—	—
(XIII)	68.52, 68.89	11.63, 11.89	68.32	11.47	19.29, 19.38	19.52
(XIV)	70.63, 70.68	10.69, 11.17	70.56	10.66	18.93, 19.00	18.51
(XVI)	63.97, 63.91	10.98, 10.85	63.81	10.71	17.29, 17.18	17.14
(XVII)	65.68, 65.75	10.35, 10.20	65.98	10.06	16.97, 16.74	16.35
(XIX)	69.09, 69.11	10.78, 10.53	69.19	10.32	—	—
(XX)	71.08, 71.06	9.87, 9.62	71.40	9.59	—	—

Saponifying the acetate of methylethylbutyryl carbinol (IX). A mixture of 3 g of acetate (IX) and 7 ml 10% aqueous alcoholic solution of caustic soda was heated for 1 hour over the water-bath. The alcohol was distilled off under vacuum, the residue saturated with potash, extracted with ether, and dried with magnesium sulfate. 2 g of methylethylbutyryl carbinol (XII) was obtained.

B.p. 69-70° (11 mm), 178-179° (675 mm), N_D^{20} 1.4310, d_4^{20} 0.9173; MR 40.70; calc. 40.67.

Found %: C 66.36, 66.45; H 11.31, 11.35. $C_8H_{16}O_2$.
Calculated %: C 66.62; H 11.18.

The semicarbazone melted at 118-120° (from benzene)

Found % N 20.50, 20.68. $C_9H_{19}O_2N_3$.
Calculated %: N 20.89.

Methylethyl-β-methoxybutyryl carbinol (XV). a) 22 g of the allyl ketone (III) was gradually added with stirring to a solution of 0.85 g caustic potash in 100 g methanol, and the reaction mixture boiled over the water-bath for 6 hours. Methyl acetate and methanol were distilled off in vacuum, the residue diluted with water, saturated with potash, extracted with ether, and dried with magnesium sulfate. 19 g of the methoxy carbinol (XV) was obtained.

B.p. 66-67° (1.5 mm), 90-92° (10 mm), n_D^{20} 1.438, d_4^{20} 0.9705, MR 47.37; calc. 46.93.

Found %: C 61.83, 61.51; H 10.53, 10.64. $C_9H_{18}O_3$.
Calculated %: C 62.04; H 10.41.

From the data in Table 2 and Figs. 1 and 2, it is evident that when haloids are introduced as substituents in the phenyl groups of 1,5-diphenylthiocarbazone the absorption maxima are displaced toward the long-wave region with the exception of the p-fluoro-substituted derivative whose long-wave maximum coincides with that for dithizone. The introduction of iodine as a substituent causes a more intense displacement toward the long-wave region than in the case of chlorine and bromine, substitution in the meta-position causing less displacement than in the ortho- and para-positions. The introduction of a second haloid atom causes an additional displacement of the absorption maxima, for example, by 32 mμ in the case of the 2,4-dichloro-substituted derivative.

b) 10 g of the propenyl ketone (IV) was gradually added with stirring to a solution of 0.35 g caustic potash in 50 g methanol, and the reaction mixture boiled over the water bath for 4 ½ hour. After further treatment as before 9 g of the methoxy carbinol (XV) was obtained of b.p. 91-93° (10 mm), n_D^{20} 1.4375. The semicarbazone melted at 151-152°, and showed no depression with preceding sample.

Splitting off methanol from the methylethyl-β-methoxybutyryl carbinol (XV). 17 g of the methoxy ketone (XV) was heated in vacuum (90 mm) in the presence of 0.2 g p-toluenesulfonic acid over the boiling water bath. After driving off the methanol the residue was distilled in oil pump vacuum (2 mm) 12.5 g of the methylethylcrotonyl carbonyl (XVIII) was obtained.

B.p. 55-57° (2 mm), 74-75° (10 mm), n_D^{20} 1.4595, d_4^{20} 0.9455, MR 41.12; calc. 40.21.

Found %: C 67.54, 67.62; H 10.41, 10.15. $C_8H_{14}O_2$.
Calculated %: C 67.56; H 9.93.

Acetylation of the methylethylcrotonyl carbinol (XVIII). 4 g of the α-ketol (XVIII) was gradually added with cooling to 5 g acetic anhydride containing a drop of concentrated sulfuric acid. After heating over the water bath for 1½ hours the reaction mixture was diluted with water, neutralized with soda, the separating oil extracted with ether, and dried with magnesium sulfate. 4.1 g of the above-described acetate (IV) was obtained of b.p. 105-107° (10 mm); n_D^{20} 1.4585.

Hydrogenation of the methylethylcrotonyl carbinol (XVIII). 4.5 g of the unsaturated α-ketol (XVIII) in 15 ml alcohol solution was hydrogenated in the presence of a Pt catalyst. The theoretical amount of hydrogen required for one double bond was absorbed. The product was distilled under atmospheric pressure. 3.9 g of the hydroxyketone (XII) was obtained of b.p. 178-179° (675 mm). The semicarbazone melted at 119-120°, and showed no depression with the above-described sample.

Addition of aniline to the acetate of the methylethylcrotonyl carbinol (IV). A mixture of 4.5 g of the propenyl α-acetoxy ketone (IV), 5 g aniline, 1.5 ml water and 12 ml dioxan was boiled with reflux condensing for 8 hours. On distilling the reaction mixture in vacuum 6 g of the acetate of methylethyl-β-phenylaminobutyryl carbinol was obtained as a viscous oil of b.p. 145-148° (1 mm). The hydrochloride, after recrystallization from mixed alcohol and acetone, melted at 161-162°.

Found %: N 4.78, 5.09. $C_{16}H_{24}O_3NCl$.
Calculated %: N 4.46.

Similarly by boiling a mixture of 2.5 g of the allyl acetoxy ketone (III), 3 g aniline, 1 ml water, and 8 ml dioxan, 2.6 g of the acetate of methylethyl-β-phenylaminobutyryl carbinol was obtained, of which the hydrochloride melted at 161-162°, and showed no depression with the preceding sample.

The other compounds shown in Tables 1 and 2 were obtained in a similar way, the results of which are given in Table 3.

SUMMARY

1. It has been shown that the acetates of methylethylvinylethinyl carbinol, methyl-n-propylvinylethinyl carbinol, and 1-vinylethinyl cyclohexanol-1, like the acetate of dimethylvinylethinyl carbinol, can be easily hydrated in solutions of acetic acid in the presence of mercuric acetate at 40-50°, forming the corresponding allyl α-acetoxy ketones.

2. It has been established that the allyl acetoxy ketones thus obtained, on heating in acetic acid solution in the presence of mercuric acetate or sodium acetate, are isomerized into the corresponding α-acetoxy ketones, with shifting of the double bond into the conjugated position.

3. A series of conversions of the above-described unsaturated α-acetoxy ketones has been studied.

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INVESTIGATIONS IN THE FIELD OF SUBSTITUTED 1,5-DIPHENYLTHIOCARBAZONE

VI. SYNTHESIS AND INVESTIGATION OF THE PROPERTIES OF MONO- AND DIHALOID-SUBSTITUTED 1,5-DIPHENYLTHIOCARBAZONE

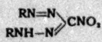
P.S. Pelkis, R.G. Dubenko and L.S. Pupko

The synthesis of substituted 1,5-diphenylthiocarbazone with electron-donor substituents was previously described [1-3]. Spectrophotometric investigations indicated that substituents of this type displace the thion-thiolic equilibrium [4] in nonpolar solvents in the direction of the thionic form. When electron-acceptor substituents are introduced the thion-thiolic equilibrium is displace towards the thiolic form. This may be seen from the data of the spectrophotometric investigation of 1,5-di-(p-trifluoromethyl-mercaptophenyl)-thiocarbazone [3] and 1-phenyl-5-(2'4'-dibromophenyl)-thiocarbazone [5]. The synthesis of 1,5-di-(p-bromophenyl)-thiocarbazone has been described in literature; the authors gave no data on its elementary analysis however and they did not investigate its absorption spectrum [6].

It was of interest to synthesize a number of haloid-substituted 1,5-diphenylthiocarbazones to study the influence of substituents on the thion/thiolic ratio in solution, the color of these compounds and their chemical properties. The arylthiocarbazones described below were synthesized by the formazyl method [6,7].

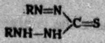
Table 1 gives the nitroformazyl derivatives synthesized as intermediate products. They are colored substances which crystallize in the form of needles or plates. The monohaloid-substituted compounds crystallize well from dioxan , the dihaloid-substituted from methanol.

TABLE 1

Nitroformazyls with the General Formula  $\left.\begin{array}{l}RN{=}N\\RNH{-}N\end{array}\right\rangle CNO,$

Expl. No.	R	Yield (%)	Melting point	Empirical formula	Nitrogen analysis (%)	
					Found	Calculated
1	o-Chlorophenol.	87	151—152° (decomp)	$C_{13}H_9O_2N_5Cl_2$	20.30, 20.43	20.71
2	m-Chlorophenol.	95	112—113	$C_{13}H_9O_2N_5Cl_2$	20.86, 20.92	20.71
3	p-Chlroophenol.	82	172—173	$C_{13}H_9O_2N_5Cl_2$	20.43, 20.51	20.71
4	o-Bromophenyl.	97	138—139	$C_{13}H_9O_2N_5Br_2$	16.63, 16.03	16.39
5	m-Bromophenyl.	97	153—155	$C_{13}H_9O_2N_5Br_2$	16.18, 16.22	16.39
6	o-Iodophenyl.	83	137	$C_{13}H_9O_2N_5I_3$	13.56, 13.51	13.44
7	m-Iodophenyl	78	157	$C_{13}H_9O_2N_5I_2$	13.18, 13.29	13.44
8	p-Iodophenyl.	83	186—187	$C_{13}H_9O_2N_5I_2$	13.57, 13.49	13.44
9	p-Fluorophenyl.	90	135—136	$C_{13}H_9O_2N_5F_2$	22.78, 22.83	22.95
10	m-Fluorophenyl.	90	103—104	$C_{13}H_9O_2N_5F_2$	22.64, 22.73	22.95
11	2,4-Dichlorophenyl.	97	170—171	$C_{13}H_7O_2N_5Cl_4$	16.91, 16.85	17.20
12	2,4-Dibromophenyl.	83	142—143	$C_{13}H_7O_2N_5Br_4$	12.11, 12.20	11.96
13	2,4-Diiodophenyl.	54	103—105	$C_{13}H_7O_2N_5I_4$	8.91, 8.87	9.05

TABLE 2

Arylthiocarbazones with the General Formula 

$$\begin{matrix} RN{=}N \\ RNH{-}NH \end{matrix}\Big\rangle C{=}S$$

Expl. No.	R	Yield (%)	Melting point	Empirical formula	Nitrogen analysis (%)	
					Found	Calculated
1	o-Chlorophenol.	98	112—113°	$C_{13}H_{10}N_4Cl_2S$	16.80, 17.03	17.23
2	m-Chlorophenol.	79	142—143	$C_{13}H_{10}N_4Cl_2S$	16.97, 16.85	17.23
3	p-Chlorophenol.	76	146—147	$C_{13}H_{10}N_4Cl_2S$	17.32, 17.15	17.23
4	o-Bromophenyl.	64	139—140	$C_{13}H_{10}N_4Br_2S$	13.23, 13.35	13.52
5	m-Bromophenyl.	61	156—157	$C_{13}H_{10}N_4Br_2S$	13.19, 13.31	13.52
6	o-Iodophenyl.	87	128	$C_{13}H_{10}N_4I_2S$	11.16, 11.21	11.02
7	m-Iodophenyl.	74	149	$C_{13}H_{10}N_4I_2S$	11.24, 11.31	11.02
8	p-Iodophenyl.	89	157	$C_{13}H_{10}N_4I_2S$	11.08, 11.11	11.02
9	p-Fluorophenyl.	54	145—146	$C_{13}H_{10}N_4F_2S$	18.93, 18.85	19.18
10	m-Fluorophenyl.	65	141	$C_{13}H_{10}N_4F_2S$	18.78, 18.94	19.18
11	2,4-Dichlorophenyl.	29	129	$C_{13}H_8N_4Cl_4S$	13.79, 13.95	14.21
12	2,4-Dibromophenyl.	44	134	$C_{13}H_8N_4Br_4S$	9.88, 9.92	9.79
13	2,4-Diiodophenyl.	30	124	$C_{13}H_8N_4I_4S$	7.29, 7.22	7.37
14	2-Methyl-4-bromophenyl.	28	168	$C_{15}H_{14}N_4Br_2S$	12.52, 12.45	12.67
15	2,5-Dimethyl-3,6-dibromophenyl.	32	164	$C_{17}H_{16}N_4Br_4S$	9.14, 9.05	8.92

As may be seen from Table 1 good yields are obtained for the haloid-substituted nitroformazyls. All compounds decompose on melting. Like all other nitroformazyl derivatives they are soluble in aqueous and alcoholic alkalis and are precipitated from these solutions by dilute acids. The monohaloid-substituted compounds dissolve in nonpolar solvents producing a yellowish-green color. The dihaloid-substituted compounds are more difficultly soluble. The synthesized arylthiocarbazones are given in Table 2.

The thiocarbazones are crystalline substances with a brown, black or dark-green color, frequently possessing a metallic luster. Compounds of this series dissolve in hydrocarbons and chlorinated hydrocarbons, giving a green color. As distinct from other thiocarbazones some of the compounds of this series (Table 2, No. 2, 3, 4,6) dissolve in acetone, alcohols and certain hydrocarbons to give a yellow or yellow-green color. It must be pointed out that haloid-substituted 1,5-diphenylthiocarbazones dissolve more readily in aqueous alkalis than alkyl- and alkoxy-substituted compounds. The haloid- substituted 1,5-diphenylthiocarbazones were investigated spectrophotometrically. Solutions of the coloring agents with a concentration of $6.6 \cdot 10^{-5}$ mole were used for the measurements.

Table 3 gives the absorption maxima of the coloring agents, the molar extinctions of both maxima and their α-ratio. All the measurements were carried out in benzene with the exception of the p-fluoro-substituted derivative for which the measurements were carried out in acetone.

For the data in Table 2 and Fig. 1 and 2 it is evident that when haloids are introduced as substituents in the phenyl groups of 1,5 diphenylthiocarbazone the absorption maxima are displaced toward the long-wave region with the exception of the p-fluoro-substituted derivative whose long-wave maximum coincides with that of dithizone. The introduction of iodine as a substituent causes a more intense displacement toward the long-wave region than in the case of chlorine and bromine, substitution in the meta-position causing less displacement than in the ortho- and para positions. The introduction of a second haloid atom causes an additional displacement of the absorption maxima, for example, by 33 mμ in the case of the 2,4-dichloro-substituted derivative.

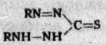
The decrease in the intensity of the long-wave maximum in these compounds with a simultaneous increase in the intensity of the short-wave maximum is very interesting. This phenomenon indicates that the thion-thiolic equilibrium in the solution is displaced toward the thiolic form [4] (Fig. 1 and 2). An external manifestation of this fact is the readier solubility of the compounds of this series in aqueous alkalis than is the case with alkyl- and alkoxy-substituted 1,5-diphenylthiocarbazones. The values of α- for the majority of the compounds is equal to or less than unity. It must be pointed out that with the introduction of electron-acceptor substituents in the phenyl groups of dithizone the molar coefficient of extinction is decreased, the latter having a value several times less than that for dithizone. On the other hand when dithizone contains electron-donor substituents, particularly in the para-position, i.e. where the conjugated chain is lengthened, the molar coefficient of extinction is several times greater than that for dithizone [2,3].

EXPERIMENTAL

The arylthiocarbazones given in Table 2 were synthesized by the modified formazyl method [8,9] certain deviations from the method being employed for the individual compounds. A description of the synthesis of two thiocarbazones of this series (Table 2) is given below.

1,5-Di-(4-iodophenyl)-thiocarbazone. 5 g of 4-iodoaniline was added with cooling to a mixture of 12 cc of concentrated hydrochloric acid and 21 cc of water and diazotized with 2 g of sodium nitrite, the mixture being cooled and mechanically stirred. The diazo solution was added with stirring to a mixture of 102 g of sodium acetate and 51 cc of glacial acetic acid. 4 g of nitromethane was added after 10 minutes. After stirring for 6 hours the formazyl derivative was precipitated as a cherry-colored deposit. This was filtered off, washed with water and then with alcohol and ether. After drying under vacuum the product was recrystallized from methanol. The yield was 4.9 g (83%), the mp was 186-187° (decom.). 1.2 g of the nitroformazyl derivative was suspended in 150 cc of ethyl alcohol and the mixture was saturated with gaseous ammonia and hydrogen sulfide until the cherry color changes to yellow. The solution was poured on to ice and the pinkish thiocarbohydrazide precipitated was filtered off and treated with 2% alcoholic alkali in the cold. The cherry-red solution was filtered off and the thiocarbazone was precipitated with 1% hydrochloric acid. The product was purified by reprecipitating 3 times from alcoholic alkali diluted with hydrochloric acid, washed with water and then with a small amount of alcohol and ether. After drying under vacuum the product was in the form of dark-green crystals with a metallic luster. The yield was 0.63 g (89%), the mp 157°. It was soluble in chloroform and benzene, the color of the solutions being green.

TABLE 3

Arylthiocarbazones with the General Formula  $\begin{matrix} RN{=}N \\ RNH{-}NH \end{matrix}\rangle C{=}S$

Expl. No.	R	λ max$_1$ (in mμ)	λ max$_2$ (in mμ)	$E_1 \cdot 10^4$	$E_2 \cdot 10^4$	$\alpha = \frac{E_2}{E_1}$
1	o-Chlorophenyl.	465	645	3.26	3.68	1.12
2	m-Chlorophenyl.	460	631	2.3	2.38	1.03
3	p-Chlorophenyl.	452	626	2.9	2.9	1.00
4	o-Bromophenyl.	475	640	2.0	2.2	1.10
5	m-Bromophenyl.	440	640	1.57	1.3	0.83
6	p-Bromophenyl.	454	638	1.9	2.3	1.21
7	o-Iodophenyl.	475	655	4.2	4.3	1.02
8	m-Iodophenyl.	455	645	2.4	2.25	0.94
9	p-Iodophenyl.	460	660	3.2	3.18	0.99
10	m-Fluorophenyl.	420	625	2.64	2.22	0.8
11	p-Fluorophenyl.	445	620	3.13	2,5	0.8
12	2,4-Dichlorophenyl.	455	665	4.0	3.2	0.8
13	2,4-Dibromophenyl.	445	645	1.72	1.7	0.99
14	2,4-Diiodophenyl.	470	675	1.83	1.53	0.83
15	2-Methyl-4-bromophenyl.	460	630	3.77	7.5	2.0
16	2,5-Dimethyl-3,6-dibromophenyl.	450	630	5.44	7.03	1.29

1,5-Di-(2,4-Diiodophenyl)-thiocarbazone. The initial 2,4-diiodoaniline was obtained from aniline and iodine monochloride under conditions modified by us [10]. 24.4 g of dichloramine B was dissolved in glacial acetic acid and 35.7 g of potassium iodide added to it gradually with stirring. The solution of iodine monochloride had a dark-orange color. A solution of iodine monochloride in acetic acid was added dropwise to 10 g of aniline with stirring. The liquid which had a brown color was poured into a large quantity of water to decompose the aniline acetate. The dark-brown precipitate formed was treated with a 5% solution of caustic alkali to remove the benzenesulfonamide ($C_6H_5SO_2NH_2$); it was then filtered, washed with water and alcohol and dried in air. It had an mp of 94-95°. The yield was 26 g (71%).

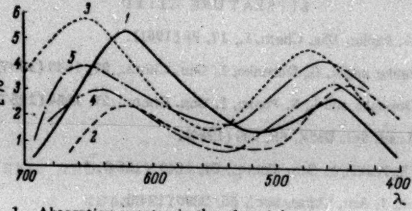


Fig. 1. Absorption spectra in the ultraviolet.
1) 1,5-Diphenylthiocarbazone. 2) 1,5-Di-(4-fluorophenyl)-thiocarbazone. 3) 1,5-Di-(2-iodophenyl)-thiocarbazone. 4) 1,5-Di-(3-iodophenyl)-thiocarbazone. 5) 1,5-Di-(4-iodophenyl)-thiocarbazone.

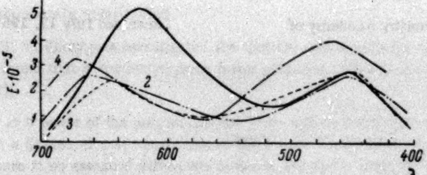


Fig. 2. Absorption spectra in the ultraviolet.
1) 1,5-Diphenylthiocarbazone. 2) 1,5-Di-(2,4-dichlorophenyl)-thiocarbazone. 3) 1,5-Di (1,4-Dibromophenyl)-thiocarbazone. 4) 1,5-Di-(2,4-diiodophenyl)-thiocarbazone.

2 g of 2,4-diiodoaniline was suspended in 7.8 cc of nitric acid (d 1.4) and 24 cc of water and diazotized at room temperature with 2.3 g of sodium nitrite in 7 cc of water. (At lower temperatures a considerable part of the amine remains undiazotized.) The filtered solution of the diazonium salt which had a straw-yellow color was added with stirring to a mixture of 65.2 g of sodium acetate and 35 cc of glacial acetic acid. After 15 minutes 2.6 g of nitromethane was added. The yellow color of the solution changed to cherry-red. After stirring for 4 hours the precipitate formed was filtered off and washed with water until there was no odor of acetic acid. After drying under vacuum the product was recrystallized from methanol. It was in the form of orange-red crystals and had an mp of 103-105°. The yield was 54%.

The nitroformazyl derivative was suspended in alcohol and the solution was saturated with gaseous ammonia and hydrogen sulfide until the red color of the solution changed to light-orange. The solution was poured on to ice and the thiocarbohydrazide which was precipitated as fine crystals was filtered off and washed with water. The thiocarbazide was again dissolved in 1% alcoholic alkali in the cold and precipitated from the solution by 1% dilute sulfuric acid. The precipitated product was black. It was purified by reprecipitating 3 times from dilute alcoholic alkali with sulfuric acid. The precipitate was filtered off, washed with water and then with a small quantity of alcohol and ether. After recrystallizing from methanol black crystals with an mp of 124° were obtained. The yield was 30%. It was soluble in organic solvents, the solutions having a green color.

SUMMARY

1. 13 mono- and dihaloid-substituted 1,5-diphenyl-3-nitroformazanes and 15 mono- and dihaloid-substituted 1,5-diphenylthiocarbazones were synthesized.

2. Haloid-substituted arylthiocarbazones were investigated spectrophotometrically. It was shown that when haloids are introduced into the phenyl groups of 1,5-diphenylthiocarbazones the intensity of the long-wave maximum is decreased with a simultaneous increase in the intensity of the short-wave maximum. This means that in haloid-substituted arylthiocarbazones the thion-thiolic equilibrium is displaced toward the thiolic form.

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SYNTHESIS AND POLYMERIZATION OF METHOXY RING-SUBSTITUTED STYRENES

I. SYNTHESIS AND POLYMERIZATION OF MONOMETHOXYSTYRENES

N.P. Zapevalova and M.M. Koton

The methoxy derivatives of styrene included among those derivatives of the latter which have not been closely studied until now. Whereas the synthesis of methoxystyrenes has been fairly fully developed [1] their polymerization has not been adequately investigated.

P. P. Shorygin and N. V. Shorygina investigated the thermal polymerization of o- and p-methoxystyrenes at 100, 150 and 170° and found that p-methoxystyrene forms polymers with a higher degree of polymerization than o-methoxystyrene [2].

Matsui showed that as a result of the polymerization of p- and m-methoxystyrenes at 165-170° transparent thermoplastic masses with a degree of polymerization of 255 for the para-isomer and 367 for the meta-isomer were obtained and that there is no essential difference between the meta- and para-isomers [3]. Melville and his co-workers [4] studied the copolymerization of p-methoxystyrene and methylmethacrylate at 60° by the dilatometer method.

According to patent data, co-polymers of methoxystyrenes and dienes treated with tertiary amines are used to obtain insoluble ion-exchange resins [5].

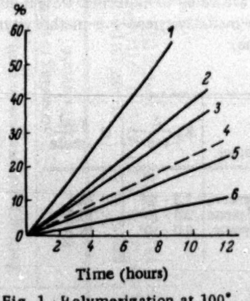


Fig. 1. Polymerization at 100°. 1) o-Methoxystyrene. 2) m-Methylstyrene. 3) p-Methylstyrene. 4) Styrene. 5) p-Methoxystyrene. 6) m-Methoxystyrene.

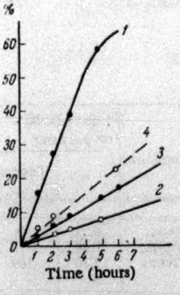


Fig. 2. Polymerization at 110°. 1) o-Methoxystyrene. 2) m-Methoxystyrene. 3) p-Methoxystyrene. 4) Styrene.

In order to investigate under comparable conditions the influence of a methoxy group in the benzene ring of styrene on the polymerization process and the properties of the polymers obtained we studied the kinetics of the polymerization of o-, m- and p-methoxystyrenes in the absence of initiators at 100, 110 and 125° and examined the properties of the compounds obtained.

The polymerization of the methoxystyrenes was carried out in sealed glass ampoules by heating in an oil thermostat with an accuracy of temperature regulation of ± 0.5°. The ampoules were filled with freshly-distilled monomer and after freezing 3-4 times in dry ice and evacuating for 30 minutes they were opened. The yield of polymer was determined by precipitating from benzene solutions with methanol followed by drying to constant weight. To obtain reliable results we carried out parallel experiments (error 3-4%).

Fig. 1-3 give the results of the investigation of the rate of polymerization of three isomeric methoxystyrenes and unsubstituted styrene. The maximum polymerization rate was found with o-methoxystyrene which polymerizes much faster than the other isomers and faster than styrene. They may be arranged in order of rate of polymerization as follows: o-methoxystyrene > styrene > p-methoxystyrene > m-methoxystyrene.

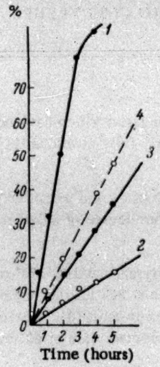


Fig. 3. Polymerization at 125°. 1) o-Methoxystyrene. 2) m-Methoxystyrene. 3) p-Methoxystyrene. 4) Styrene.

The higher rate of polymerization of the ortho-substituted styrenes can evidently be explained by the presence of the powerful inductive influence of the substituent in the immediate vicinity of the electron shell of the vinyl group.

From the comparison of the polymerization rates of the m- and p- methoxystyrenes with the corresponding methyl styrenes at 100° (Fig.1) it is evident that the introduction of a methoxyl group in the styrene has less influence on the polymerization rate than the introduction of a methyl group. Monomethoxystyrenes polymerize almost twice as slowly as the corresponding methylstyrenes [6].

Polymers of monomethoxystyrenes are colorless thermoplastic masses soluble in benzene and carbon tetrachloride but insoluble in alcohols. Their characteristic viscosities in benzene and Vicat thermal stabilities were measured. From the data in Table 1 it is evident that the polymer of p-methoxystyrene is more highly molecular and thermally stable than the other polymers of methoxystyrenes. The investigated substances may be arranged in the following order according to molecular weight and thermal stability: p-methoxystyrene > o-methoxystyrene > > m-methoxystyrene.

TABLE 1

Name of the monomer	Properties of the polymer	
	η	Thermal stability
o-Methoxystyrene.	0.71	106
n-Methoxystyrene.	0.42	97
p-Methoxystyrene.	1.10	109

TABLE 2

Name of the monomer	$K_0\ \frac{1}{sec}$	$U\ \frac{kcal}{mole}$
o-Methoxystyrene.	$3.3 \cdot 10^5$	13.3
m-Methoxystyrene.	$2.0 \cdot 10^3$	15.3
p-Methoxystyrene.	$8.0 \cdot 10^3$	15.7

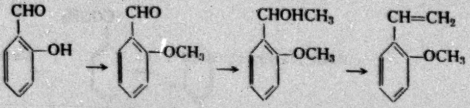
The values of the pre-exponential factor (K_0) and the energy of activation (U) were calculated for the isomeric methoxystyrenes from the equation $K = K_0 e^{-\frac{U}{RT}}$; these values are given in Table 2.

EXPERIMENTAL

The synthesis of o-methoxystyrene was carried out according to the system

TABLE 3

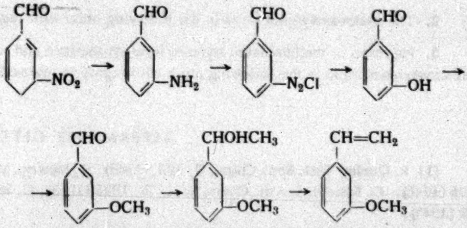
Monomer	Boiling point (pressure in mm).		n_D^{20}		d_4^{20}		MR_D		Purity of the monomer (%)
	Found	According to data in literature	Found	According to data in literature	Found	According to data in literature	Found	Calculated	
o-Methoxystyrene.	62° (3), 85 (6)	61—62° (3) [1]	1.5580	1.5560 [1]	1.0034	1.009 [2]	43.0	42.8	99.7
m-Methoxystyrene.	67 (3), 70—71 (5)	67 (5) [3], 89 (14) [10]	1.5540	1.5586 [3], 1.5540 [10]	0.9919	0.9894 [3]	43.2	42.8	99.4
p-Methoxystyrene.	63 (3), 105 (20)	104 (20) [2]	1.5585	1.5600 (17°) [2]	0.9956	1.0015 [2] (17°)	43.1	42.8	99.8



o-Methoxybenzaldehyde was obtained by the methylation of salicylic aldehyde with dimethyl sulfate in alkali [7]; it had a bp of 124° (18 mm) and mp 36°. The yield was 80%.

o-Methoxyphenylmethylcarbinol was synthesized by the following method: an ethereal solution of 0.14 mole of o-methoxybenzaldehyde was added to a solution of 0.2 mole of methyl magnesium bromide; the mixture was heated for 1 hour and left overnight after which it was decomposed by a 5% solution of acetic acid. The ethereal solution was separated, washed and dried over anhydrous magnesium sulfate. In view of the fact that the carbinol is easily dehydrated when distilled under vacuum it was not isolated in the free form but was immediately dehydrated in the presence of hydroquinone over freshly-calcined potassium bisulfate [2].

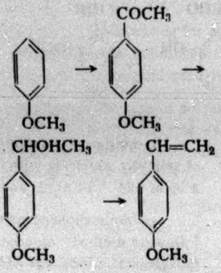
The synthesis of m-methoxystyrene was carried out according to the system



m-Hydroxybenzaldehyde was obtained by the reduction of m-nitrobenzaldehyde followed by diazotization and decomposition of the diazo compound with water [8]. The m-hydroxybenzaldehyde was isolated in the form of crystals with mp 101-102°. The yield was 50%.

m-Methoxybenzaldehyde was obtained in a similar manner to the ortho-isomer with a yield of 80% and was isolated in the form of a colorless liquid with bp 111-112° (12 mm) [9]. m-Methoxyphenylmethylcarbinol was obtained in a similar manner to the ortho-isomer with a yield of 85-90%; the bp was 107-108° (2 mm). Dehydration was carried out as indicated above. The yield of m-methoxystyrene was 40%.

The synthesis of p-methoxystyrene was carried out according to the system



p-Methoxyacetophenone was obtained by the acetylation of anisole with acetic anhydride in the presence of iodine [11]; it was in the form of a colorless liquid with bp 132° (4 mm) which crystallized out on cooling and had an mp of 37°. The yield was 25%. p-Methoxyphenylmethylcarbinol was obtained by the reduction of p-methoxyacetophenone with aluminium isopropylate in a solution of isopropyl alcohol [12]; it was a thick colorless liquid with bp 104-106° (2 mm). The yield was 70-80%. p-Methoxystyrene was obtained in a similar manner to the ortho-isomer.

The monomers were colorless transparent liquids with an odor of styrene. The physical properties of the monomethoxystyrenes are given in Table 3.

SUMMARY

1. o-, m- and p-methoxystyrenes were synthesized and the process of their polymerization at 100, 110 and 125° was studied.

2. The methoxystyrenes stand in the following order with regard to rate of polymerization: o- > p-> m-.

3. Polymers of methoxylated styrenes were synthesized and some of their properties determined. Polymethoxystyrenes stand in the following order with regard to molecular weight and thermal stability: p-> o-> m-.

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SYNTHESIS AND POLYMERIZATION OF METHOXY RING-SUBSTITUTED STYRENES

II. SYNTHESIS AND POLYMERIZATION OF DIMETHOXYSTYRENES

N.P. Zapevalova and M.M. Koton

Until recently, methoxy-substituted styrenes have been little studied. Whereas there were some inadequate data in literature on monosubstituted methoxystyrenes, disubstituted styrenes were almost completely neglected. Only the synthesis of 3,4- and 2,6-dimethoxystyrenes was described [1]; it was shown that they form polymers [2], the 2,6-dimethoxystyrene forming a low molecular polymer with a softening point of 78-82°. We synthesized 2,5-dimethoxystyrene for the first time and studied the kinetics of the thermal polymerization of 2,5- and 3,4-dimethoxystyrenes at 100, 110, 125 and 135° by the dilatometer method. Fig. 1-3 give the results obtained; it was shown that 2,5- and 3,4-dimethoxystyrenes have a slower rate of polymerization compared with unsubstituted styrene. The relative position of the methoxy group in the benzene ring influences the polymerization rate of dimethoxystyrenes. At all the investigated temperatures 2,5-dimethoxystyrene polymerizes much faster than the 3,4-isomer, a fact which agrees with the results obtained previously for other substituted styrenes [3].

The values of the pre-exponential factor (K_0) and the energy of activation (U) were calculated for the dimethoxystyrenes and compared with the data for 2,5- and 3,4-dimethylstyrenes [4].

The differences in the energies of activation for the 2,5- derivatives of methyl- and methoxystyrenes are striking. Fig. 1 gives the polymerization rates of 2,5 and 3,4 disubstituted methyl- and methoxy derivatives of styrene at 100°.

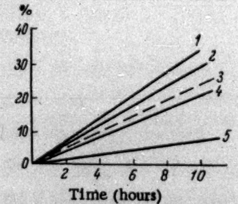


Fig. 1. Polymerization at 100°. 1) 2,5-Dimethylstyrene. 2) 3,4-Dimethylstyrene. 3) Styrene. 4) 2,5-Dimethoxystyrene. 5) 3,4-Dimethoxystyrene.

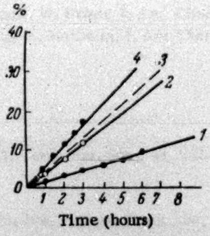


Fig. 2. Polymerization at 110°. 1) 3,4-Dimethoxystyrene. 2) 2,5-Dimethoxystyrene. 3) Styrene. 4) 3,4-Dimethoxystyrene at 135°.

It was established that dimethylstyrenes have a polymerization rate almost twice as high as that of the corresponding dimethoxystyrenes, the following order being found: 2,5-dimethylstyrene > 3,4-dimethylstyrene > styrene > 2,5-dimethoxystyrene > 3,4-dimethoxystyrene.

TABLE 1

Monomers	$K_0\ \frac{1}{sec}$	$U\ \frac{kcal}{mole}$	References in literature
2,5-Dimethoxystyrene. .	$5 \cdot 10^4$	17 ± 1.0	—
3,4-Dimethoxystyrene. .	$3 \cdot 10^4$	17.5 ± 0.5	—
2,5-Dimethylstyrene. . .	$2.3 \cdot 10^5$	15.0	[4]
3,4-Dimethylstyrene.....	$4.4 \cdot 10^6$	17.0	[4]

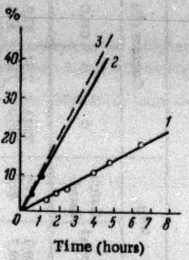
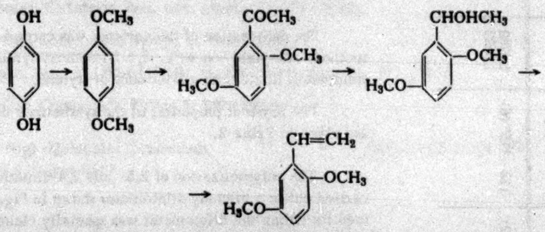


Fig. 3. Polymerization at 125° 1) 3,4-Dimethoxystyrene. 2) 2,5-Dimethoxystyrene. 3) Styrene.

Polymers of dimethoxystyrenes are transparent thermoplastic masses soluble in benzene and insoluble in alcohols. The polymer of 2,5-dimethoxystyrene has a softening point of 98° (according to Vicat) and a characteristic viscosity [2] of 0.7 for reprecipitated samples. The polymer of 3,4-dimethoxystyrene has a softening temperature of 93° and a characteristic viscosity of 3.3.

EXPERIMENTAL

2,5-Dimethoxystyrene was obtained by the following system



1,4-Dimethoxybenzene was obtained by the methylation of hydroquinone with dimethylsulfate in a solution of alkali; it was in the form of colorless crystals with mp 55° [5]; the yield was 45%. 2,5-Dimethoxyacetophenone was obtained by the acetylation of 1,4-dimethoxybenzene with acetyl chloride in the presence of anhydrous aluminium chloride [6]; the yield was 80%. It was a colorless liquid with bp 156-158° (15 mm) which crystallized on cooling; it had an mp of 20° [7].

When the ketone was reduced by the Meyerwein-Ponndorf method with aluminium isopropylate in anhydrous isopropyl alcohol 2,5-dimethoxyphenylmethylcarbinol was obtained with a yield of 70%, it was in the form of colorless crystals with mp 98-99°.

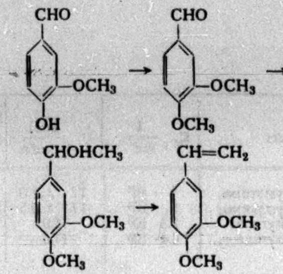
Found %: OCH_3 34.07. $C_{10}H_{14}O_3$.
Calculated %: OCH_3 34.06.

By dehydration of the carbinol over potassium bisulfate by the usual method 2,5-dimethoxystyrene was obtained; it was a colorless transparent liquid with an odor of styrene.

3,4 Dimethoxystyrene was obtained according to the system

TABLE 2

Monomer	Boiling point (pressure in mm)		d_4^{20}		n_D^{20}		MR_D		Content (%)			
	Found	Data in literature [1]	Found	Data in literature [1]	Found	Data in literature [1]	Found	Calculated	C	H	CH_3O	Double bond
3,4-Dimethoxystyrene. .	110—111° (2)	113—115° (6)	1.0780	1.087	1.5720	1.5703	49.9	49.5	73.14	7.27	37.8	99.8
2,5-Dimethoxystyrene. .	113 (5)	—	1.0622	—	1.5584	—	49.7	49.5	73.10	7.27	37.6	99.8
Calculated									73.17	7.32	37.8	—



Veratric aldehyde was obtained by methylating vaniline (3-methoxy-4-hydroxybenzaldehyde) by the usual method; it was in the form of crystals with mp 42-43° and the yield was 80-90% [8].

3,4-Dimethoxyphenylmethylcarbinol was obtained by reacting methyl magnesium bromide (0.2 mole) with veratric aldehyde (0.15 mole) in ethereal solution followed by decomposition of the reaction mass with a solution of aluminium chloride; it was a colorless liquid with mp 145-150° (4 mm), n_D^{20} 1.5440.

Found %: C 66.1; H 7.61; OCH_3 33.7. $C_{10}H_4O_3$.
Calculated %: C 65.98; H 7.63; OCH_3 34.06.

The dehydration of the carbinol was carried out by the usual method; the yield was 40%. 3,4 Dimethoxystyrene was a colorless transparent liquid with a faint odor of styrene.

The physical properties of the synthesized dimethoxystyrenes are given in Table 2.

The polymerization of 2,5- and 3,4-dimethoxystyrenes was carried out in a mercury dilatometer shown in Fig. 4. The mercury used for filling the dilatometer was specially cleaned. After carefully washing with chrome mixture, water, alcohol and ether and drying the dilatometer was filled with mercury up to the line b-b'. The monomer was placed in the distillation flask and the apparatus evacuated for 30 minutes withthe cock K open; the monomer was frozen with dry ice. The monomer was then distilled into the polymerization bulb, the first 2-3 drops being collected in the space f by turning the apparatus around the ground glass part S. After filling the capillary tube was sealed at the point h by means of the concentrated flame of a burner. After cooling, air was admitted to the vacuum and the mercury poured into the capillary tube through the open end a; the apparatus which was now ready for use was placed in a thermostat with an accuracy of temperature regulation of ± 0.1°. The yield of polymer was determined by two comparative methods, i.e. by bromination and by precipitation with methyl alcohol from benzene solution. When the graphs of the relationship of polymerization with time were drawn the mean values found by the different methods were employed.

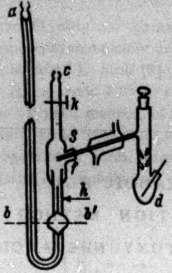


Fig. 4. Apparatus for polymerization
Explanation in the text.

SUMMARY

1. 2,5-Dimethoxystyrene was obtained and characterized for the first time.

2. The polymerization process of 3,4- and 2,5-dimethoxystyrenes at 100, 110 and 125° was studied by the dilatometer method.

3. It was shown that 2,5-dimethoxystyrene has a higher polymerization rate at all temperatures than 3,4-dimethoxystyrene.

4. 2,5- and 3,4 dimethoxystyrenes polymerize more slowly than the corresponding dimethylstyrenes.

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THE PREPARATION OF ω-HYDROXYPENTADECANOIC ACID BY THE "CROSSED" ELECTROLYTIC CONDENSATION METHOD

I. THE ELECTROLYTIC CONDENSATION OF ω-ACETOXYUNDECANOIC ACID AND THE MONOETHYL ESTER OF ADIPIC ACID

G.E. Svadkovskaya, S.A. Voitkevich, E.K. Smolyaninova
and V.N. Belov

ω-Hydroxyacids (from C_{15} to C_{17}) with a straight carbon chain serve as the initial raw material for the synthesis of macrocyclic lactones which are very valuable perfumes with an odor of natural musk. The method usually employed for preparing these acids are successive elongations of the carbon chain in multistage processes by condensing with sodiomalonic ester [1,2], sodio-acetic ester [3], etc. The α,ω-dicarboxylic acids or α,ω-diols obtained by these methods may be converted into ω-hydroxy acids by partial reduction [4,5] or partial oxidation [6], respectively. This method of synthesis involves certain difficulties, however, and gives a low yield of the desired ω-hydroxyacids.

We considered it advantageous to use the "crossed" electrolytic condensation method for obtaining ω-hydroxy acids and, in particular, ω-hydroxypentadecanoic acid. In this instance, as distinct from the ordinary Kolbe reaction, molecules of different kinds of acids or polyesters of dicarboxylic acid are condensed; in consequence, together with the main reaction leading to the formation of the required product two processes, of equal probability, of the electrolytic condensation of like molecules take place.

$$\left.\begin{array}{l}\mathrm{RCOO^-}\\ \mathrm{R'COO^-}\end{array}\right\}\xrightarrow{-2e}\mathrm{R-R'+2CO_2}\qquad\begin{array}{l}\mathrm{2RCOO^-\xrightarrow{-2e}R-R+2CO_2}\\ \mathrm{2R'COO^-\xrightarrow{-2e}R'-R'+2CO_2}\end{array}$$

The yield of the main product of "crossed" condensation (R-R') is, therefore, considerably lower than with ordinary condensation by the Kolbe reaction.

To synthesize ω-hydroxypentadecanoic acid, which was our intention, the monoethyl ester of adipic acid may be condensed with undecenylic acid or its derivatives (followed by conversion of the resultant 15-carbon atom acids into ω-hydroxypentadecanoic acid). Tentative experiments using undecylic and ω-bromoundecanoic acids gave negative results: when electrolysis was carried out in an aqueous medium the required products could only be obtained with a yield of a few percent. Much better results were obtained by condensing the monoethyl ester of adipic acid with ω-hydroxydecanoic acid and particularly with ω-acetoxyundecanoic acid. The latter modification of the synthesis was the one studied by us most closely.

As is known from literature [7], electrolytic condensation reactions proceed most satisfactorily at platinum or iridium anodes. In the present investigation we used an anode of smooth platinum, carrying out the electrolysis without the use of a diaphragm. In the majority of works concerning "crossed" electrolytic condensation the use of ethanolic solutions of the potassium or sodium salts of the acids undergoing condensation is recommended. For example, when Ruzicka and his co-workers [8] electrolyzed the Na salts of undecylenic acid and the monomethyl ester of adipic acid in anhydrous methanol with a current density of 0.83 A/sq in. at the anode and 80-100 V their yield of pentadecenic acid, purified via the methyl ester, was 15%.

Hunsdiecker [1] obtained the methyl ester of 14-methoxy-3-methyltetradecanoic acid with a yield of 34.% from 11-methoxyundecanoic acid and the monomethyl ester of β-methylglutaric acid (methanol, current strength 5-7 A, 80-100 V). Stoll [9] condensed acetovalerianic and acetopelargonic acids (anhydrous methanol, current density at the anode 1.25 A/sq in., 50 V, temperature 40-50°) and obtained a 31% yield of 2,15-hexadecandione. In a similar manner, in a medium of anhydrous methanol pentadecenic (yield 22%), erucic (yield 34%) and brassidic (yield 34%) acids were obtained by condensing the monomethyl ester of adipic acid with undecylic, oleic and elaidic acids, respectively [10], and also palmitic (yield 30%) and arachidic (yield 25%) acids by condensing the monobenzyl ester of succinic acid, with myristic and stearic acids, respectively [11].

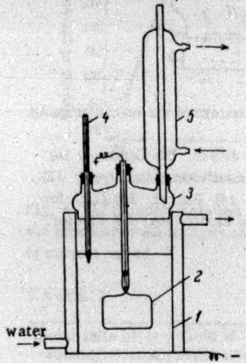

Fig. 1. Laboratory electrolyzer.
1) Electrolyzer. 2) Anode. 3) Cover.
4) Thermometer. 5) Reflux condenser.

In spite of the comparatively high yield of the reaction products electrolytic condensation in methanolic solutions must be carried out at very low current densities at the anode (0.8-1.25 A/sq in.) and high voltages (up to 100 V) because of the low electrical conductivity of the electrolyte. This method of condensation is hardly suitable for large-scale practical operations since it must be carried out with very large anode surfaces and a high consumption of electricity and there is also the danger of fire.

Like the ordinary Kolbe condensation, "crossed" electrolytic condensation may be carried out in an aqueous alcoholic or aqueous medium. In the latter case, however, the secondary processes which take place simultaneously with the electrolytic condensation reaction are on a much larger scale and the yield of the desired product is appreciably reduced.[*] In some of the published works [13] on "crossed" condensation in aqueous solutions a low yield of the main product is indicated. In some of the works [14-16] no yield at all is mentioned.

We carried out a systematic investigation of "crossed" electrolytic condensation in an aqueous medium by way of the example of the preparation of ω-hydroxypentadecanoic acid. The influence of the following factors was studied: a) the ratio of the components undergoing condensation, b) the amount of current, c) the current density, d) the temperature, e) the degree of neutralization of the acids. As a result of the investigation the optimum conditions for the synthesis of ω-hydroxypentadecanoic acid were established.

Procedure. The majority of the experiments were carried out in a 1-liter steel (steel 0) cylindrical electrolyzer, the arrangement of which is clearly shown in Fig. 1. The housing 1 was surrounded by a cooling jacket. The platinum anode 2 was located 20-30 mm from the inner wall of the housing of the electrolyzer which acted as the cathode. The glass cover 3 was equipped with tubes for the thermometer 4 and the reflux condenser 5. The current strength was up to 20 A and the voltage 12-14 V.

To carry out the electrolysis in the electrolyzer (Fig. 1) it was first charged with a prepared homogeneous aqueous solution of ω-acetoxyundecanoic acid and the monoethyl ester of adipic acid, partially neutralized with K_2CO_3 or KOH and a current was then passed, the current strength and the temperature being maintained constant. When the reaction was completed the electrolyte was discharged and divided into two parts, an upper oily layer containing the electrolytic condensation products and an aqueous layer. The oily layer was washed with water until it gave a neutral reaction and was then distilled under vacuum. The desired ω-hydroxypentadecanoic acid was isolated from the fraction boiling between 174-220° at 4 mm (consisting principally of the ethyl ester of ω-acetoxypentadecanoic acid and eicosandiol diacetate) after saponification with an alcoholic solution of caustic potash.

To carry out electrolytic condensation on a large scale in the laboratory a semicontinuous apparatus [17] designed for a current strength of 100 A was used (Fig. 2-3).

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[*] A good yield in a similar type of electrolytic condensation was indicated in one of the earlier works [12]. When potassium salts of acetic acid and the monomethyl ester of succinic acid were electrolyzed a 69.5% yield of butyric acid was obtained. The electrolysis was carried out with a small amount of the initial components, however, and the reaction product was not isolated in the free state.

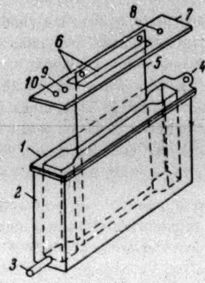

Fig. 2. Semicontinuous electrolyzer.
1) Housing of the electrolyzer. 2) Cooling jacket. 3) Connecting pipe for water feed. 4) Clamp for connecting up the negative busbar. 5) Platinum anode. 6) Anode support. 7) Ebonite cover. 8,9,10) Orifices for introducing the electrolyte, thermometer and ejector.

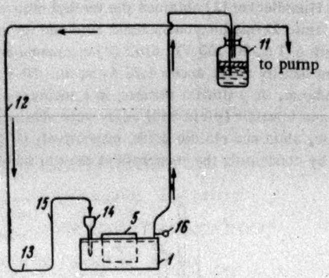

Fig. 3. Operational system of the semicontinuous electrolyzer.
1) Electrolyzer. 5) Anode. 11) Container for feed of electrolyte and division into layers. 12) Siphon. 13) Loop. 14) Funnel. 15) Cock for regulating the feed of electrolyte. 16) Ejector. 17) To the pump.

In Fig. 2 the electrolyzer 1 has a slot-shaped working chamber cooled by a water jacket 2. The platinum anode 5 is supported by the cover 7. The distance between the anode and the wall of the electrolyzer serving as the cathode was decreased in comparison with the small electrolyzer (Fig. 1) to 12 mm; this made it possible to reduce the voltage to 10-12 V. A continuous feed of electrolyte was passed into the electrolyzer (Fig. 3) from the container 11, through the siphon 12, via the loop 13 and the funnel 14. The rate of feed of the electrolyte was regulated by the cock 15. The container 11 was under a low vacuum; this ensured continuous suction of the electrolysis products and part of the electrolyte by the ejector 16. The division into layers took place in the container 11, the upper oily layer containing the condensation product of ω-acetoxyundecanoic acid and the monoethyl ester of adipic acid remaining in the container while the lower aqueous layer continued to circulate through the electrolyzer until the initial acids were completely exhausted. After this a fresh portion of electrolyte was introduced into the container and the process was restarted.

Results of the investigation. 1. The amount of current required for more complete electrolytic condensation was established by a number of experiments at a current strength of 16 A (current density at the anode 37.5 A/sq in.), a temperature of 40-45° and a charge of 150 g of ω-acetoxyundecanoic acid (0.614 mole) and 320.6 g of the monoethyl ester of adipic acid (1.842 mole), neutralized with 148.5 g of K_2CO_3, in 367 cc of water. After passing each 30 Ah, electrolysis was discontinued, the upper layer of the reaction products was separated and weighed and the aqueous layer again electrolyzed.

Fig. 4 shows the relationship between the total weight of the products of electrolysis and the amount of current passed. The process is almost finished after passing 225 Ah of current, which for this charge corresponds to a current consumption of ~ 342%.

2. The optimum ratio of the components was established by a series of experiments in which, other circumstances being equal (current strength 18 A, current density at the anode 38 A/sq in., temperature 40-45°, 8.3 mole KOH/1 mole of mixture), only the ratio of the initial substances – ω-acetoxyundecanoic acid and the monoethyl ester of adipic acid – was changed. As may be seen from the data in Table 1 the maximum yield of ω-hydroxypentadecanoic acid was obtained with a molar ratio of 1:5 for the components.

3. To find the relationship between the yield of the desired hydroxy acid and the current density at the

anode a series of experiments was carried out at a current strength of 16-18 A, 35-40° and a molar ratio of 1:2 for the initial components. In these experiments, changing the working area of the anode and, therefore, the current density at the anode we established that the most complete process in the desired direction takes place at a current density of 25-38 A/sq in. A decrease in the current density leads to a reduction in the yield of ω-hydroxypentadecanoic acid. The relationship between the yield of ω-hydroxypentadecanoic acid and the current density at the anode is shown in Fig. 5.

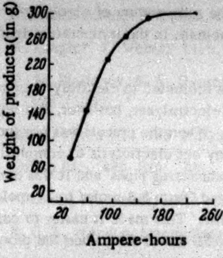

Fig. 4. Relationship between the yield of the products of electrolysis and the amount of current passed.

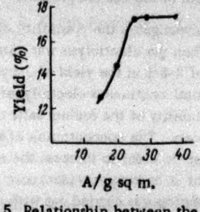

Fig. 5. Relationship between the yield of ω-hydroxypentadecanoic acid and the current density at the anode.

TABLE 1

Molar ratio of ω-acetoxyundecanoic acid and the monoethyl ester of adipic acid.	Yield of ω-hydroxypentadecanoic acid (as a % of the theoretical with respect to ω-acetoxyundecanoic acid.
1 : 1	12.5—13.5
1 : 2	17—18
1 : 3	21—22
1 : 4	22.5—23.5
1 : 5	25—27

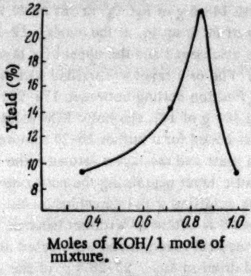

Fig. 6. Relationship between the yield of ω-hydroxypentadecanoic acid and the degree of neutralization of the initial acids.

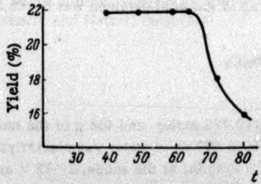

Fig. 7. Relationship between the yield of ω-hydroxypentadecanoic acid and the temperature of the process.

4. Since caustic potash is formed at the cathode during the process of electrolysis, in spite of its partial neutralization by the CO_2 evolved saponification of the initial esters and the products of electrolysis is always possible and this must lead to a reduction in the yield of the required product of electrolytic condensation. From this it follows that only the partial neutralization of the the initial acids should favor successful electrolytic synthesis. From experiments in which the percentage of neutralization of the initial acids was changed and the current strength (18-20 A), the temperature (35-40°) and the molar ratio of the initial ω-acetoxyundecanoic acid and the monoethyl ester of adipic acid (1:3) were all kept constant it was established that the maximum yield of ω-hydroxypentadecanoic acid is obtained with 100% neutralization of the monoethyl ester of adipic acid and 50% neutralization of ω-acetoxypentadecanoic acid, which corresponds to 9.875 mole KOH /1 mole of mixture. The relationship between the yield of ω-hydroxypentadecanoic acid and the degree of neutralization of the initial components is shown in Fig. 6.

5. The investigations in the laboratory electrolyzer (Fig. 1) were generally carried out at 35-45°. With the changeover to large scale laboratory operations in the semicontinuous apparatus (Fig. 2) it was desirable to work at higher temperatures since this allows, firstly, a reduction in the voltage and, secondly, facilitates the withdrawal of heat via the cooling surface.

In order to examine the possibility of increasing the temperature a series of experiments was conducted in which, other circumstances being equal (current strength 90 A, current density at the anode 27 A/sq in., voltage 10-12 V, 8.3 moles H_2O/1 mole of mixture, 0.875 mole KOH/1 mole of mixture), the temperature varied between 40-80°. From the data obtained (Fig. 7) it follows that the increase of the temperature of electrolysis to 65° has no influence on the yield of ω-hydroxypentadecanoic acid. A further increase in the temperature leads to a reduction in the yield of the desired product.

6. We also investigated the possibility of replacing potassium salts subjected to electrolytic condensation by sodium salts. When the electrolysis was carried out in the laboratory electrolyzer, however, this replacement led to a reduction of 3-5% in the yield of ω-hydroxypentadecanoic acid. When the process was conducted on a large scale in the semi-continuous electrolyzer it was not possible to carry out electrolysis to completion; because of the low solubility of the sodium salts the latter obstructed the connecting pipes and it was necessary to discontinue the process. The concentration of the initial acids was reduced (from 8.3 moles to 11 moles of H_2O per mole of mixture) in order to increase the solubility of the sodium salts. This made it easier to conduct the process; the yield of ω-hydroxypentadecanoic acid was, however, still 3-5% lower than when the process of electrolytic condensation was carried out with potassium salts.

Examples of the electrolytic condensation process and the formation of ω-hydroxypentadecanoic acid.

1. To carry out the electrolysis, the electrolyzer was first charged with the prepared electrolye consisting of 100 g of ω-acetoxyundecanoic acid (0.41 mole) and 356.7 g of the monoethyl ester of adipic acid (2.05 moles) neutralized with 148.5 g of K_2CO_3 in 367 cc of water. After passing 226 Ah at a current strength of 16 A, a current density of 38 S/ sq in. at the anode, 12-14 V and a temperature of 40-45° electrolysis was discontinued, the electrolyte discharged and the upper oily layer (300-350 g) containing the electrolytic condensation products was separated. The oily layer was washed with hot water until it gave a neutral reaction and was distilled under vacuum. The fraction boiling betweeen 174-220° at 4 mm (60-65 g) was collected. This fraction was heated for 1 hour with 400 g of 10% alcoholic KOH solution after which 200 cc of benzene was added to the solution and the mixture was boiled for a further 15-20 minutes. After the completion of heating 400 cc of water was added to the reaction mass and the layers formed – the upper benzene layer containing eicosanediol and the lower aqueous-alcoholic layer containing the potassium salt of ω-hydroxypentadecanoic acid – were separated. The lower layer was acidified with hydrochloric acid until it gave an acid reaction with congo. The ω-hydroxypentadecanoic formed was extracted with hot benzene (200-250 cc). The benzene extract was washed with water until it gave a neutral reaction and was cooled at + 10°. The precipitated ω-hydroxypentadecanoic acid was filtered off and dried in air. 27-28.5 g of the acid was obtained, this amount representing 25-27% of the theoretical yield with respect to ω-acetoxyundecanoic acid. The mp of the acid obtained was 85-85.5°, the acid number 217.7 (calculated 217).

Found %: C 69.96, 70.07; H 11.79, 11.86; OH 6.63. $C_{15}H_{30}O_3$.
Calculated %: C 69.77; H 11.63; OH 6.59.

2. A mixture consisting of 158 g of ω-hydroxydecanoic acid (0.782 mole) and 408 g of the monoethyl ester of adipic acid (2.346 moles), neutralized with 153.4 g of KOH in 467 cc of water was electrolyzed. After passing 285 Ah at a current strength of 60 A, a current density of 17.7 A/sq in. at the anode, 10-12 V and a temperature of 45-55° the electrolysis was discontinued and the oily layer (400-420 g) was separated from the electrolyte; after washing, this layer was distilled under vacuum. The fraction boiling between 190-220° at 4 mm was treated in the manner indicated above.

14.2 g of ω-hydroxypentadecanoic acid (mp 85-85.5°, acid number 218, % OH 6.5) was obtained, i.e. 7% of the theoretical yield with respect to ω-hydroxydecanoic acid.*

SUMMARY

1. The "crossed" electrolytic condensation of ω-acetoxyundecanoic acid and the monoethyl ester of adipic acid in an aqueous medium was investigated.

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* The experiments in this direction were of a tentative character. Possibly, the yield could be increased.

2. The optimum conditions of the process permitting a yield of 25-27% of the theoretical of ω-hydroxypentadecanoic acid to be obtained were established.

3. In the electrolytic condensation of ω-hydroxydecanoic acid and the monoethyl ester of adipic acid ω-hydroxypentadecanoic acid was obtained with a 7% yield of the theoretical.

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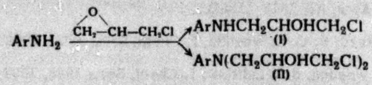
REACTION PRODUCTS OF EPICHLOROHYDRIN WITH AROMATIC AMINES

I. γ -CHLORO-β -HYDROXYPROPYL DERIVATIVES OF AMINES AND THEIR TRANSFORMATION PRODUCTS

N.N. Vorozhtsov, Jr. and S.I. Kutkevichus

The reaction of epichlorohydrin with aromatic amines yields various types of products. Evidently, the first reaction is the addition of the amine to the epoxide grouping to yield, in accord with the K. A. Krasusky [1] rule, the N-γ -chloro-β -hydroxy-propyl derivatives of the amine [2,3].

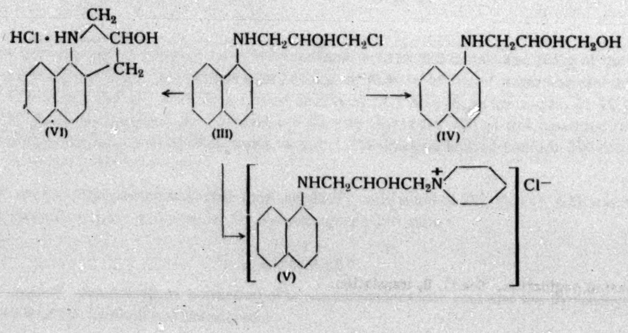


$$ArNH_2 \xrightarrow{\overset{O}{CH_2-CH}-CH_2Cl} \begin{cases} \underset{(I)}{ArNHCH_2CHOHCH_2Cl} \\ \underset{(II)}{ArN(CH_2CHOHCH_2Cl)_2} \end{cases}$$

At sufficiently high reaction temperatures (above 100°) the secondary amines of benzene derivatives, and also the primary amines of the naphthalene series, yield 1,2,3,4-tetrahydro-3 hydroxyquinoline derivatives [4]. Here in the case of the secondary aliphatic-aromatic amines of benzene derivatives it was shown that the heterocyclic ring is formed as the result of the cyclization, with cleavage of hydrogen chloride, of the initially formed N (γ -chloro - β -hydroxypropyl) -N -alkylarylamine [5].

The same mechanism is also assumed for the formation of 1,2,3,4-tetrahydro-3-hydroxybenzoquinolines from naphthylamines, although here experimental proof is lacking. Up to now the mono-N- γ -chloro- β -hydroxypropyl derivatives of naphthylamines are also unknown; N-(γ -chloro- β -hydroxypropyl)-1-naphthylamine, described in a number of patents [6], is actually the isomeric 1,2,3,4-tetrahydro-3-hydroxy-7,8-benzoquinoline hydrochloride [7].

It was established by us that N-mono-(γ -chloro- β -hydroxypropyl)-1-naphthylamine (III) can be obtained in smooth manner by the long reaction of 1-naphthylamine with an equimolar amount of epichlorohydrin at room temperature. The reaction time can be reduced by raising the temperature (to 90-100°).

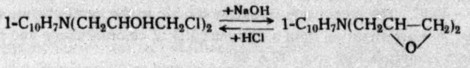


The structure of (III) was shown by its conversion into the β, γ-dihydroxypropyl derivative (IV) and into N-[γ-(N'-1-naphthyl)-amino-β-hydroxypropyl]-pyridinium chloride (V), and also into 1,2,3,4-tetrahydro-3-hydroxy-7,8-benzoquinoline hydrochloride (VI) (in 83% of the theoretical yield) by heating in chlorobenzene at 135-145°. The smooth progress of the cyclization reaction shows that the formation of 1,2,3,4-tetrahydro-3-hydroxy-7,8-benzoquinoline, the same as of the N-alkyl-1,2,3,4-tetrahydro-3-hydroxyquinolines, proceeds through the stage of the N-γ-chloro-β-hydroxypropyl derivative.

The reaction with an equimolar amount of epichlorohydrin at room or somewhat higher temperature also permits obtaining other N-mono-γ-chloro-β-hydroxypropyl derivatives of amines, studied but slightly up to now. The derivatives of 2-naphthylamine (I, Ar = 2-$C_{10}H_7$), 4-aminobiphenyl (I, Ar = 4-$C_6H_4C_6H_5$) and p-toluidine (I, Ar = $C_6H_4CH_3$) (described earlier [2]) were prepared by us.

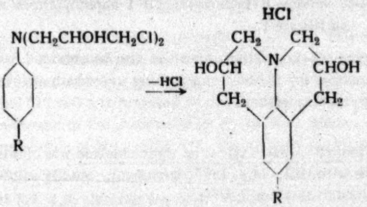
The reaction of excess epichlorohydrin with amines leads to the formation of N, N-bis-γ-chloro-β-hydroxypropyl derivatives of amines (first obtained under different conditions by I. T. Strukov [3]). In this manner benzidine and 2,6-naphthylenediamine gave the corresponding N, N, N', N'-tetrakis-γ chloro-β-hydroxypropyl derivatives, while N-ethylnaphthylamine gave N-ethyl-N-(γ chloro-β-hydroxypropyl)-1-naphthylamine.

The last compound, and also bis-N,N-(γ-chloro-β-hydroxypropyl)-1-naphthylamine, by treatment with anhydrous alkali in ether solution [3,8] are converted into the corresponding β, γ-epoxypropyl derivatives, which when treated with hydrogen chloride are converted into the N-γ-chloro-β-hydroxypropyl derivatives, for example



$$1\text{-}C_{10}H_7N(CH_2CHOHCH_2Cl)_2 \underset{+HCl}{\overset{+NaOH}{\rightleftarrows}} 1\text{-}C_{10}H_7N(CH_2\underset{O}{\underbrace{CH-CH_2}})_2$$

The heating of 4-N,N-bis-(γ-chloro-β-hydroxypropyl)-aminobiphenyl and N,N-bis-(γ-chloro-β-hydroxypropyl)-p-toluidine at 140-150° gave the corresponding julolidine derivatives (VII, R = C_6H_5, CH_3).



(VII)

EXPERIMENTAL

N-(γ-Chloro-β-hydroxypropyl)-1-naphthylamine. A mixture of 114.6 g (0.8 mole) of 1-naphthylamine and 74.0 g (0.8 mole) of epichlorohydrin was kept at room temperature for 16 days. The obtained neutral (indicator – methyl red) viscous reaction mass, devoid of epichlorohydrin odor, was dissolved in chlorobenzene (700 ml), and then hydrogen chloride was passed into the solution at a rate of 100-120 bubbles a minute. The solution turned cloudy and the hydrochloride began to precipitate; after 30-35 minutes the solution became clear again and the formation of the hydrochloride ceased. After letting settle for 30 minutes the precipitate of 1-naphthylamine hydrochloride was filtered and washed with 28 ml of chlorobenzene. Weight 13.0 g.

Hydrogen chloride was again passed into the filtrate. After 35-40 minutes a crystalline hydrochloride began to deposit copiously. The passage of hydrogen chloride was terminated when a viscous mass began to separate. After letting stand for an hour the hydrochloride was filtered, washed with chlorobenzene (50 ml), and air-dried. Weight 142.0 g, m.p. 164° (decompn.).

The hydrochloride, contaminated with a small amount of viscous material, was transferred to a flask and treated with 200 ml of a chlorobenzene – methyl alcohol mixture (40:1). After the viscous material had dissolved the hydrochloride was filtered, washed with the same mixture (50 ml), and dried at 40-50°. Weight 131.5 g (60.3%), m.p. 165.5° (decompn.). The hydrochloride was treated with water (500 ml), first at room temperature, and then at 40-50°. Here it changed into a thick viscous mass (evidently, due to hydrolysis of the salt to the free base), which after decanting the top water layer (a) was washed in the same flask twice with water (30 ml portions). For conversion to the hydrochloride the mass was treated with 150 ml of water and then 20% hydrochloric acid was added until acid to litmus. The viscous mass crystallized on shaking, and the obtained hydrochloride was filtered, washed with 1% hydrochloric acid solution (50 ml), and dried at 40-50°. Weight 101.5 g, m.p. 167.5° (decompn.). The product was dissolved in 400 ml of methyl alcohol, treated with activated carbon, and to the filtrate was added slowly and with stirring a 5% water solution of sodium bicarbonate until alkaline to litmus, followed by dilution with water until turbidity formation ceased. After standing for 3 hours the upper water layer was decanted, while the viscous oil (free base) was dissolved in 200 ml of ether, shaken with 3% aqueous sodium bicarbonate solution, and washed with distilled water until the test for alkali and for chloride ion was negative. The ether was removed by distillation, and the residue was dried in vacuo (2-3 mm) at a water bath temperature of 60-70° for 45 minutes. We obtained 71.5 g of transparent, nearly colorless oil, extremely viscous at room temperature, which was dissolved in 15 ml of a 3:1 mixture of chlorobenzene and petroleum ether (b.p. 45-65°). The mass crystallized after standing for a day. The precipitate was filtered (filtrate 1), washed with a mixture (3:2) of chlorobenzene and petroleum ether (12 ml), and dried in the air. Weight 56.5 g, m.p. 44.6 - 45.8°. The precipitate is readily soluble in the usual organic solvents, and is difficultly soluble in petroleum ether. Recrystallization from a mixture (3:1) of chlorobenzene and petroleum ether with drying in the air gave colorless crystals with m.p. 47.6-48°.

Found %: C 66.4, 66.1; H 6.0, 6.1; N 5.9, 5.9.
$C_{13}H_{14}ONCl$. Calc. %: C 66.2; H 6.0; N 5.9

An additional 24.1 g of N-(γ-chloro-β-hydroxypropyl)-1-naphthylamine with m.p. 43.1 -44.2° was isolated from water solution (a) and filtrate 1.

N-(γ-Chloro-β-hydroxypropyl)-1-naphthylamine can also be obtained from epichlorohydrin and 1-naphthylamine by heating the mixture for 12 hours on a boiling water bath or for 18 hours at 60-70°. However, here the yield is lower than at room temperature.

N-(γ-Chloro-β-hydroxypropyl)-1-naphthylamine Hydrochloride was obtained by saturating a solution of the free base in chlorobenzene with HCl. M.p. 170° (decompn.), readily soluble in alcohol and in dilute hydrochloride acid. The compound hydrolyzes in water.

Found %: C 57.1, 57.1; H 5.6, 5.7; N 5.1, 5.1.
$C_{13}H_{14}ONCl \cdot HCl$ Calc. %: C 57.4; H 5.6; N 5.1.

N (γ-Chloro-β-hydroxypropyl)-1-naphthylamine Acid Oxalate. A solution of 3.0 g of N-(γ-Chloro-β-hydroxypropyl)-1-naphthylamine (m.p. 44.6 -45.5°) in 3 ml of anhydrous alcohol was treated with a solution of 1.15 g of anhydrous oxalic acid in 3 ml of anhydrous alcohol. Recrystallization from anhydrous alcohol gave colorless crystals, m.p. 144.1 - 144.3° (decompn.).

Found %: C 55.3, 55.1; H 5.2, 5.0.
$C_{13}H_{14}ONCl \cdot C_2H_2O_4$. Calc. %: C 55.3; H 5.0.

Reaction of N-(γ-Chloro-β-hydroxypropyl)-1-naphthylamine with Pyridine. A mixture of 6.0 g of N-(γ-chloro-β-hydroxypropyl)-1-naphthylamine (m.p. 44.6-45.8°), 3.0 g of pyridine and 8.0 ml of chlorobenzene was heated in an oil bath for 6 hours at 100-110° and for 4 hours at 110-120°. The reaction mixture was diluted with 5 ml of chlorobenzene. The crystalline deposit was filtered, washed with acetone, and dried at 40-50°. Weight 6.3 g, m.p. 192.1-194.0°. The compound is readily soluble in water and alcohol, and difficultly soluble in chlorobenzene and acetone. It contains chloride ion. The product was dissolved in a mixture of acetone and methyl alcohol (4:1). Evaporation of part of the solvent gave light-green needle crystals with m.p. 200-201°.

Found γ: C 68.6, 68.7; H 6.1, 6.1; N 8.8, 8.9.
$C_{18}H_{19}ON_2Cl$. Calc. %: C 68.7; H 6.1; N 8.9.

N-(β, γ-Dihydroxypropyl)-1-naphthylamine (Acid Oxalate). A mixture of 6.0 g of N-(γ-chloro-β-hydroxypropyl)-1-naphthylamine (m.p. 47.6-48.0°), 1.2 g of sodium hydroxide, 25 ml of 96% alcohol and 3 ml of water was heated for 8 hours at 75-85°. The reaction mass was diluted with water (until the solution ceased to turn cloudy) and then extracted with ether. The ether was distilled off and the residue was dried at 100° (3-5 mm). Weight of residue (thick oil) 3.8 g.

A solution of 3.2 g of the residue and 1.4 g of oxalic acid (anhydrous) in 12 ml of alcohol was placed in a desiccator over calcium chloride. After 2 days the crystals of N-(β, γ-dihydroxypropyl)-1-naphthylamine acid oxalate were filtered and washed with alcohol (4 ml). Weight 2.5 g, m.p. 119.5-121.0° (decompn.). The compound is readily soluble in alcohol and in acetone. Recrystallization from acetone gave colorless crystals with m.p. 123.6 - 124.3° (decompn.).

Found %: C 58.7, 58.8; H 5.9, 5.7; N 4.7, 4.7.
$C_{13}H_{15}O_2N$. $C_2H_2O_4$. Calc. %: C 58.6; H 5.6; N 4.6.

1,2,3,4-Tetrahydro-3-hydroxy-7,8-benzoquinoline (Hydrochloride). A mixture of 23.6 g of N-(γ-chloro-β-hydroxypropyl)-1-naphthylamine with m.p. 46.1-46.7° and 12.5 ml of chlorobenzene was heated at 135-145° for 8 hours. The 1,2,3,4-tetrahydro-3-hydroxy-7,8-benzoquinoline hydrochloride obtained here was filtered, washed with chlorobenzene, and dried at 40-50°. The weight of hydrochloride with m.p. 246.5° (decompn.) was 19.5 g (82.7%). When the experiment was repeated the yield of 1,2,3,4-tetrahydro-3-hydroxy-7,8-benzoquinoline hydrochloride ranged from 80 to 83%.

A portion of the hydrochloride was recrystallized from methyl alcohol using activated carbon. The 1,2,3,4-tetrahydro-3-hydroxy-7,8-benzoquinoline hydrochloride-was obtained as colorless crystals with m.p. 247° (decompn.). The m.p. given in the literature is 249° [7].

Found %: C 66.1, 66.2; H 5.8, 6.0; N 6.0, 5.8; chloride ion 15.1, 15.1. $C_{13}H_{13}ON \cdot HCl$.
Calc. % C 66.2; H 6.0; N 5.9; chloride ion 15.0.

N-(γ-Chloro-β-hydroxypropyl)-2-naphthylamine Hydrochloride. A mixture of 14.3 g (0.1 mole) of 2-naphthylamine, 9.3 g (0.1 mole) of epichlorohydrin and 25.0 ml of methyl alcohol was heated on the water bath (bath temperature 30-40°) for 22 hours, and then the reaction mixture was kept at room temperature for 13 days. Then a part of the methyl alcohol (17 ml) was removed by distillation, and the residue was kept at room temperature for another 5 days. Treatment of the reaction mass in the same manner as described for the 1-naphthylamine derivative gave the hydrochloride of N-(γ-chloro-β-hydroxypropyl)-2-naphthylamine as colorless crystals. M.p. 147° (decompn.).

Found %: C 57.4, 57.6; H 5.7, 5.8; chloride ion 12.9, 13.1.
$C_{13}H_{14}NOCl \cdot HCl$. Calc. %: C 57.4; H 5.6; chloride ion 13.0.

4-N-(γ-Chloro-β-hydroxypropyl)-aminobiphenyl. A mixture of 16.9 g (0.1 mole) of 4-aminobiphenyl and 9.3 g (0.1 mole) of epichlorohydrin was heated fro 32 hours at 35-40°. Then the mass was diluted with 20 ml of methyl alcohol and again heated for 28 hours at 40-50°. The crystalline precipitate obtained on cooling was filtered and washed with methyl alcohol. Weight 17.1 g, m.p. 76.2-77.4°. Two recrystallizations from methyl alcohol gave the compound as colorless crystals with m.p. 88.5-89.3°.

Found %: C 68.9, 69.1; H 6.2, 6.3; N 5.5, 5.7.
$C_{15}H_{16}ONCl$. Calc. %: C 68.9; H 6.2; N 5.4.

N-(γ-Chloro-β-hydroxypropyl)-p-toluidine. A mixture of 10.7 g (0.1 mole) of p-toluidine and 9.3 g (0.1 mole) of epichlorohydrin was kept at room temperature for 4 days. Recrystallization of the solidified reaction mass from petroleum ether gave N-(γ-chloro-β-hydroxypropyl)-p-toluidine as white needless with m.p. 80.8-81.2°. The m.p. given in the literature is 81-82° [2].

Found %: N 7.3, 7.2. $C_{10}H_{14}ONCl$. Calc. %: N 7.2.

Preparation of the Hydrochlorides of the N,N-Bis- γ-chloro-β-hydroxypropyl Derivatives of p-Toluidine, m-Aminophenol, 1-Naphthylamine and 2-Naphthylamine. The amine was reacted with 4 equivalents of epichlorohydrin at room temperature. The hydrochlorides were isolated by saturation of the isobutyl alcohol-diluted reaction mass (3 parts of alcohol to 1 part of amine) with hydrogen chloride; in the case of 2-naphthylamine the excess epichlorohydrin was vacuum distilled before adding the isobutyl alcohol, while in the case of 1-naphthylamine, after distilling off the epichlorohydrin, the reaction mass was diluted with carbon tetrachloride (35 parts for 1 part of amine). The length of reaction and the results are summarized in the table.

3,9-Dihydroxy-6-methyljulolidine. A mixture of 10.7 g of p-toluidine and 37.0 g of epichlorohydrin was kept at room temperature for 8 days, and then it was heated in an oil bath for 9 hours at 140-150°. The reaction mass was dissolved in 100 ml of ether, and the solution was saturated with HCl. The thick mass that remained after decanting off the top ether layer was dissolved in 7 ml of isobutyl alcohol. After 4 days the crystalline precipitate was filtered and washed with isobutyl alcohol. Weight 3.1 g. The precipitate was disolved in 15 ml of methyl alcohol, made alkaline with 5% aqueous sodium bicarbonate solution, and diluted with 25 ml of water. The crystalline precipitate was filtered and washed with a mixture (1:1) of methyl alcohol and water (6 ml). Recrystallization from methyl alcohol gave 3,9-dihydroxy-6-methyljulolidine as colorless needless with m.p. 162.0 -162.5°.

Found %: C 71.3, 71.1; H 7.9, 8.0.
$C_{13}H_{17}O_2N$. Calc. % : C 71.2; H 7.8.

3,9-Dihydroxy-6-methyljulolidine Hydrochloride. A solution of 0.3 g of 3,9-dihydroxy-6-methyljulolidine in 6 ml of methyl alcohol was saturated with HCl. The precipitate was filtered and washed with methyl alcohol (3 ml). Weight 0.2 g, m.p. 194.5° (decompn.). Recrystallization from methyl alcohol gave the compound as colorless needles with m.p. 198° (decompn.).

Found %: N 5.4, 5.6.
$C_{13}H_{17}O_2N \cdot HCl$. Calc. %: N 5.5.

4-N, N-Bis-(γ-chloro-β-hydroxypropyl)-aminobiphenyl. A mixture of 16.9 g (0.1 mole) of 4-aminobiphenyl and 37.0 g (0.4 mole) of epichlorohydrin was heated for 61 hours at 45-50°. The precipitate of 4-N, N-bis-(γ-chloro- β-hydroxypropyl)-aminobiphenyl was filtered and washed with epichlorohydrin (10 ml). Weight 23.4 g, m.p. 113.5-114.3°. After recrystallization from methyl alcohol, m.p. 115.2-115.8°.

Found %: C 61.1, 61.0; H 6.0, 6.1; N 4.1, 4.1. $C_{18}H_{21}O_2NCl$. Calc. %:
C 61.0, H 6.0, N 4.0.

3,9-Dihydroxy-6-phenyljulolidine. A solution of 10.0 g of 4-N,N-bis-(γ-chloro-β-hydroxypropyl)-aminobiphenyl (m.p. 115.2-115.8°) in 10 ml of chlorobenzene was heated for 18 hours in an oil bath at 140-145°. The precipitate after cooling was filtered and washed with chlorobenzene (5 ml). Weight 2.4 g, m.p. 216° (decompn.). Recrystallization from methyl alcohol gave the hydrochloride of 3,9-dihydroxy-6-phenyljulolidine as colorless crystals with m.p. 220° (decompn.).

Found %: C 68.1, 68.0; H 6.5, 6.3; chloride ion 11.2, 11.0.
$C_{18}H_{19}O_2N \cdot HCl$. Calc. %: C 68.0; H 6.3; chloride ion 11.2.

A solution of 1.5 g of 3,9-dihydroxy-6-phenyljulolidine in 35 ml of pyridine was slowly diluted with 400 ml of distilled water with stirring. The needle crystals of the free base were filtered and washed with water. Weight 0.9 g, m.p. 157.1-158.3°. The compound is readily soluble in alcohol and pyridine, and difficultly soluble in water. Recrystallization from methyl alcohol gave 3,9-dihydroxy-6-phenyljulolidine as light-yellow rhombic crystals with m.p. 160.1-161.1°.

Found %: C 76.9, 77.0; H 6.9 , 6.9; N 5.0.
$C_{18}H_{10}O_2N$. Calc. %: C 76.9; H 6.8; N 5.0.

N,N-Bis-(β-, γ-epoxypropyl)-1-naphthylamine. A solution of 6.6 g of crude N, N-bis-(γ-chloro-β-hydroxypropyl)-1-naphthylamine (residue after distilling off the epichlorohydrin, see above) in 80 ml of ether was heated with 2.4 g of crushed sodium hydroxide for 6 hours at the boil. The ether solution was filtered and then

Starting amine	Reaction time (in days)	Melting point (decomp.)	Yield (in %)	Formula	Analysis results		
					Element (ion)	Calc. (in %)	Found (in %)
p-Toluidine	8	157.5° [in $CH_3OH + (CH_3)_2CO$]	86	$C_{13}H_{19}O_2NCl_2 \cdot HCl$	Cl^-	10.8	10.7, 10.6
m-Aminophenol	12	203° (in CH_3OH)	83	$C_{12}H_{17}O_3NCl_2 \cdot HCl$	N	4.2	4.4, 4.4
1-Naphthylamine	26	177° * (in CH_3OH)	70	$C_{16}H_{19}O_2NCl_2 \cdot HCl$	C	52.7	52.8, 53.0
					H	5.5	5.6, 5.7
					N	3.8	4.1, 4.0
					Cl^-	9.7	9.6, 9.8
2-Naphthylamine	16	167° (in C_2H_5OH)	42	$C_{16}H_{19}O_2NCl_2 \cdot HCl$	C	52.7	52.6, 52.5
					H	5.5	5.7, 5.5
					Cl^-	9.7	9.7, 9.9

* This product was obtained (in % yield) by the reaction of 2 equivalents of epichlorohydrin (for 15 days) with N-γ-chloro-β-hydroxypropyl-1-naphthylamine (m.p. 44.6-45.5°).

washed with distilled water until the test for both chloride and hydroxyl ions was negative. After distilling off the ether the residue was distilled at 3 mm in a stream of nitrogen. Most of the material distilled at 180°182°(1.7 g). N, N-Bis-(β, γ-epoxypropyl)-1-naphthylamine is a clear light-yellow oil. The Beilstein test for chlorine was negative.

Found %: C 75.6, 75.4, H 6.8, 6.7; N 6.1, 5.8
$C_{16}H_{17}O_2N$. Calc. %: C 75.3; H 6.7; N 5.5.

A solution of 1.5 g of N, N-bis (β, γ-epoxypropyl)-1-naphthylamine in 5 ml of isobutyl alcohol was saturated with HCl. The precipitate of N,N-bis-(γ-chloro-β-hydroxypropyl)-1-naphthylamine hydrochloride (1.1 g) was recrystallized from methyl alcohol. M.P. 176° (decompn.). Its mixed melting point with the hydro chloride of N,N-bis-(γ-chloro-β-hydroxypropyl)-1-naphthylamine (m.p. 177°) was not depressed.

Found %: chloride ion 9.6, 9.7.
$C_{16}H_{19}O_2NCl_2 \cdot HCl$. Calc. %: chloride ion 9.7.

N-Ethyl-N-(γ-chloro-β-hydroxypropyl)-1-naphthylamine Hydrochloride. A mixture of 20.8 g (0.1 mole) of 1-ethylaminonaphthalene and 27.8 g (0.3 mole) of epichlorohydrin was heated for 40-42 hours at 75-80°. The products with boiling point below 60° (excess epichlorohydrin and glycerol dichlorohydrin, b.p. 173.0-174.3°, $n_D^{16.9}$ 1.4807) were distilled from the reaction mixture at 3-5 mm. The residue was dissolved in 125 ml of isobutyl alcohol, and the solution was saturated with dry HCl. Weight of the precipitate 23.1 g, m.p. 157° (decompn.). The hydrochloride is readily soluble in pyridine and alcohol, and difficultly soluble in acetone. After recrystallization from a mixture of acetone and methyl alcohol, m.p. 159° (decompn.).

Found %: C 59.8, 59.9; H 6.2, 6.2; N 4.7, 4.8 chloride ion 11.9, 11.6. $C_{15}H_{18}ONCl \cdot HCl$. Calc. %: C 60.0; H 6.4; N 4.7; chloride ion 11.8.

The same product was also obtained by running the reaction at 20-30° for 16 days.

N-Ethyl-N-(β, γ-epoxypropyl)-1-naphthylamine. A solution of 22.0 g of N-ethyl-(γ-chloro-β-hydroxypropyl)-1-naphthylamine hydrochloride in 100 ml of methyl alcohol was made alkaline with 5% aqueous $NaHCO_3$ solution with stirring, and then it was diluted with water until cloudiness ceased to appear. The upper water layer was decanted, while the oil was dissolved in 175 ml of ether, treated with 5% $NaHCO_3$ solution, and then washed with water until the test for both chloride and hydroxyl ions was negative. After distilling off the ether the oil was dried in vacuo at 2-4 mm and 75-80°. We obtained 14.5 g of clear oil, fairly viscous at room temperature [the free base N-ethyl-N-(γ-chloro-β-hydroxypropyl)-1-naphthylamine.]

A solution of 10.6 g of the oil in 80 ml of ether was treated with 4.8 g of crushed sodium hydroxide, and then with mechanical stirring the solution was heated on the water bath (bath temperature 35-40°) for 8 hours. After removing the precipitate and distilling off the ether the reaction mass was distilled (at 3 mm) in a stream of nitrogen. The main fraction had b.p. 165-167° (4.0 g), and was obtained as a clear yellow liquid, quite viscous at room temperature. Based on analysis it is N-ethyl-N-(β,γ-epoxypropyl)-1-naphthylamine.

Found %: C 79.0, 79.1; H 7.6, 7.7; N 6.4, 6.3.
$C_{15}H_{17}ON$. Calc. %: C 79.3; H 7.5; N 6.2.

A solution of 1.2 g of N-ethyl-N-(β,γ-epoxypropyl)-1-naphthylamine in 5 ml of isobutyl alcohol was saturated with HCl. After recrystallization from a mixture of acetone and methyl alcohol (10:1) the N-ethyl-N-(γ-chloro-β-hydroxypropyl)-1-naphthylamine had m.p. 159° (decompn.).

Found %: chloride ion 11.7, 11.8.
$C_{15}H_{18}ONCL \cdot HCl$. Calc. %: chloride ion 11.8.

Its mixed melting point with the hydrochloride of N-ethyl-N-(γ-chloro-β-hydroxypropyl)-1-naphthylamine (m.p. 158.5°) was not depressed.

N-[γ-(N'-Ethyl-N'-1-naphthyl) amino-β-hydroxypropyl]-pyridinium Chloride. A mixture of 2.6 g of the free base N-ethyl-N-(γ-chloro-β-hydroxypropyl)-1-naphthylamine, 1.6 g of pyridine and 8.5 ml of chlorobenzene was heated in an oil bath (bath temperature 110-120°) for 10 hours. The crystalline deposit was filtered. Weight 2.4 g, m.p. 186.1-187.4°. Readily soluble in water, pyridine and alcohol, and difficultly soluble in acetone and chlorobenzene. Recrystallization from a mixture of acetone and methyl alcohol (8:1) gave colorless needles with m.p. 190.8-191.4°, and containing chloride ion.

Found %: C 69.9, 70.0; H 7.0, 6.8; N 8.5.
$C_{20}H_{23}ON_2Cl$. Calc. %: C 70.1; H 6.8; N 8.2.

N,N,N', N'-Tetrakis-(γ-chloro-β-hydroxypropyl)-benzidine. A mixture of 18.4 g (0.1 mole) of benzidine and 74.0 g (0.8 mole) of epichlorohydrin was heated on the water bath at 45-55° for 48 hours. The crystalline deposit was filtered and washed with epichlorohydrin (10 ml). Weight 29.5 g, m.p. 159.5-161.6°. The mother liquor (to which the epichlorohydrin used to wash the precipitate had been added) when heated (bath temperature 50-60°) for 36 hours gave an additional 12.7 g of the same crystalline substance with m.p. 161.0-162.0°. The product is readily soluble in alcohol and in acetone. Its recrystallization from methyl alcohol gave light-yellow needles with m.p. 164.3 164.8°.

Found %: C 52.3, 52.4; H 5.9, 6.0; N 5.1, 5.2.
$C_{24}H_{32}O_4N_2Cl_4$. Calc. %: C 52.0; H 5.8; N 5.1.

The dihydrochloride was obtained by saturating a solution of the free base in acetone with HCl. After recrystallization from acetone, m.p. 183.2° (decompn.).

Found %: C 46.0, 46.1; H 5.6, 5.6; chloride ion 11.2, 11.2.
$C_{24}H_{32}O_4N_2Cl_4 \cdot 2HCl$. Calc. %: C 46.0; H 5.5; chloride ion 11.3.

N,N,N',N'-Tetrakis-(γ-chloro-β-hydroxypropyl)-2,6-naphthylenediamine. A mixture of 1.6 g of 2,6-naphthylenediamine and 18.3 g of epichlorohydrin was heated at 70-80° for 64 hours. The precipitate was filtered and washed with 4 ml of methyl alcohol. Weight 2.2 g, m.p. 131.0-132.5°. Recrystallization from methyl alcohol gave N,N,N',N'-tetrakis-(γ-chloro-β-hydroxypropyl)-2,6-naphthylenediamine as fine needles with m.p. 136.1-137.9°.

Found %: C 49.5, 49.6; H 5.8, 5.9; N 5.0.
$C_{22}H_{30}O_4N_2Cl_4$. Calc. %: C 50.0; H 5.7; N 5.3.

SUMMARY

1. The reaction of an equimolar amount of epichlorohydrin with 1-naphthylamine gave N-(γ-chloro-β-hydroxypropyl)-1-naphthyl-amine. The structure of the product was shown by its conversion into the β,γ-

-dihydroxypropyl derivative, into N-[γ-(N'-1-naphthyl)-aminohydroxypropyl]-pyridinium chloride, and into 1,2,3,4-tetrahydro-3-hydroxy-7,8-benzoquinoline. The N-γ-chloro-β-hydroxypropyl derivatives of p-toluidine, 4-aminobiphenyl and 2-naphthylamine were obtained in a similar manner.

2. Reaction with excess epichlorohydrin gave the N,N-bis-γ-chloro-β-hydroxypropyl derivatives of p-toluidine, 4-aminobiphenyl, m-aminophenol, 1-naphthylamine and 2-naphthylamine. In a similar manner N-ethyl-N-(γ-chloro-β-hydroxypropyl)-1-naphthylamine was obtained from 1-ethylaminonaphthalene, while the corresponding N,N,N',N'-tetrakis-γ-chloro-β-hydroxypropyl derivatives were obtained from benzidine and 2,6-naphthylenediamine.

3. The treatment of N-ethyl-N-(γ-chloro-β-hydroxypropyl)-1-naphthylamine and N,N-bis-(γ-chloro-β-hydroxypropyl)-1-naphthylamine with sodium hydroxide gave the corresponding β,γ-epoxypropyl derivatives, which reverted back to the original compounds when treated with HCl.

4. N,N-Bis-(γ-chloro-β-hydroxypropyl)-p-toluidine and 4-N,N-bis-(γ-chloro-β-hydroxypropyl)-aminobiphenyl gave the corresponding julolidine derivatives.

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REACTION OF ETHERS WITH ANILINE AND AMMONIA.

I. REACTION OF DIPHENYL ETHER WITH ANILINE AND AMMONIA

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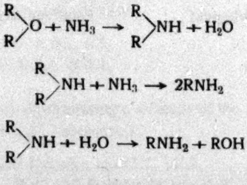
The reaction of ethers with amines and ammonia in the vapor phase in the presence of solid catalysts offers great theoretical and practical interest. E. and K. Smolensky [1], using aluminum oxide and kaolin as catalysts, first showed the possibility of preparing aliphatic amines from ammonia and an ether. Somewhat later, Mekert [2] carried out the alkylation of an aromatic amine, aniline, with dimethyl ether. A great many articles and patents have furthermore been published on the reaction of aliphatic ethers with amines and ammonia using different catalysts [1-16]. Recently investigations have been reported in which aromatic and mixed aliphatic- aromatic ethers were aminated [7-18].

The mechanism of the reaction of ethers with amines or ammonia is not clear. To explain the process of alkylation of the amino group, two schemes have been proposed. According to the first scheme [19], the alkylation by ethers proceeds stepwise with successive replacement of the hydrogen atoms on the nitrogen by alkyl groups. According to the second scheme proposed to explain the reaction of aliphatic ethers with ammonia [11] and aniline [14], the initial stage of the process consists of the replacement of the two hydrogen atoms on the nitrogen by two alkyl groups, and the formation of the less alkylated amines results from secondary processes. For example, the Baum process for the alkylation of ammonia is depicted in the following reactions



$$R_2O + NH_3 \rightarrow R_2NH + H_2O$$

$$R_2NH + NH_3 \rightarrow 2RNH_2$$

$$R_2NH + H_2O \rightarrow RNH_2 + ROH$$

The insufficient study of the reaction of ethers with amines in view of its great practical significance resulted in the need for further investigation. We have studied the reaction of ammonia and aniline with aliphatic, aromatic, and mixed ethers. All the reactions were carried out on active aluminum oxide and synthetic aluminosilicate. In the present communication the results obtained with diphenyl ether are given.

Only the reaction of diphenyl ether with ammonia has been described in the literature. Chatterjee, Sanyal, and Goswami [7] indicated that when diphenyl ether together with ammonia was passed over dehydrating catalysts, insignificant amounts of amines were formed, but the experimental data were not presented in the article. Recently N. S. Kozlov and L. F. Akhmetshina [18] have shown that when diphenyl ether in a current of ammonia was passed over active aluminum oxide at 450-475° and 8-9 atmos. pressure, aniline was obtained in 18.3% yield based on the ether used, or 70% based on the ether that reacted.

For the reaction of diphenyl ether with aniline on a catalyst under corresponding conditions we might anticipate the course of the alkylation of aniline. In this case the reaction product of most practical interest is diphenylamine. In order to judge the possibilities of the course of the processes that were of interest to us for practical use, we calculated from the most reliable data [20-25] the isobaric potentials and the equilibrium constants for several reactions of diphenyl ether with aniline and ammonia. The isobaric potential was calculated by the formula $\Delta Z_T = \Delta H_T - T\Delta S_T$. The equilibrium constant was calculated from the equation $\ln K_p = -\Delta Z_T/RT$. The heat effect and the entropy of the reaction were computed from a calculation of the temperature relationship of the specific heats of the final products and the starting materials determined by the method of Dobratz [26].

The results of the thermodynamic calculations are presented in the table. The yields were calculated for an equimolecular starting mixture.

The data given in the table indicate that the equilibrium conditions favor a reaction course in the direction of the formation of the appropriate amines.

Reaction	Temperature of process							
	450°		500°		550°		600°	
	K_p	Yield (in %)	K_p	Yield (in %)	K_p	Yield (in %)	K_p	Yield (in %)
$C_6H_5OC_6H_5 + C_6H_5NH_2 \rightleftarrows C_6H_5NHC_6H_5 + C_6H_5OH$	222	93.7	180	93.0	148	92.4	125	91.7
$C_6H_5OH + C_6H_5NH_2 \rightleftarrows C_6H_5NHC_6H_5 + H_2O$	186	93.3	180	93.1	190	93.4	209	93.5
$C_6H_5NH_2 + C_6H_5NH_2 \rightleftarrows C_6H_5NHC_6H_5 + NH_3$	0.24	48.15	0.21	47.6	0.19	46.1	0.17	44.7
$C_6H_5OC_6H_5 + NH_3 \rightleftarrows C_6H_5NH_2 + C_6H_5OH$	903	96.8	850	96.8	812	96.5	740	96.5
$C_6H_5OH + NH_3 \rightleftarrows C_6H_5NH_2 + H_2O$	46.9	87.3	34.7	85.5	26.8	83.8	21.2	82.1

When a mixture of diphenyl ether and aniline (molar ratio 2:1) was passed over synthetic aluminosilicate at 450-600°, a complex mixture of materials was obtained: along with unreacted aniline and diphenyl ether, the catalyzate contained ammonia, phenol, water, benzene, diphenylene oxide, and diphenylamine. As can be seen from Fig. 1, the main reaction product in the range 450-550° was diphenylamine, the quantity of which in the catalyzate passed through a maximum at 500-550° amounting to 13.3-12.9 mole-%. The amount of phenol in the catalyzate in experiments carried out on synthetic aluminosilicate passed through a maximum (11.6 mole-%) at 550°. The water content of the catalyzate increased continuously with rising temperature. The amount of ammonia increased in the same way; however, as seen from Fig. 1, the quantity of ammonia obtained was considerably less than that of phenol and water. With an increase in temperature, especially at 550-660°, there was a rapid increase in side reactions, which were accompanied by the formation of benzene and diphenylene oxide. Thus at 600° the benzene content of the catalyzate amounted to 9.8 mole-%, and the diphenylene oxide content to 5.0%. Elevation of the temperature was accompanied by the evolution of considerable amounts of gas, which consisted mainly of hydrogen. On active aluminum oxide the reaction of diphenyl ether with aniline proceeded less vigorously. When aniline in a stream of nitrogen was passed over synthetic aluminosilicate at 450-500°, diphenylamine was formed, but in smaller amounts than from diphenyl ether and aniline.

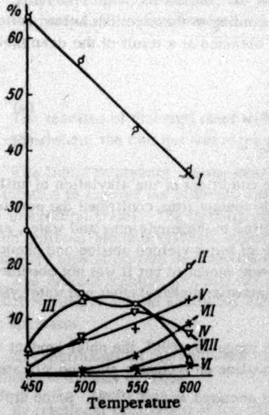


Fig.1. Effect of temperature on composition of catalyzate in alkylation of aniline by diphenyl ether on synthetic aluminosilicate.
I) diphenyl ether, II) aniline, III) diphenylamine, IV) phenol, V) water, VI) ammonia, VII) benzene, VIII) diphenylene oxide.

In a study of the effect of the time of contact on the composition of the catalyzate in the range 0.68-79.0 sec. at 500° on synthetic aluminosilicate, it was established that the amount of diphenylamine increased continuously with increasing time (Fig. 2). The water and phenol content of the catalyzate also increased continuously and considerably exceeded the amount of ammonia obtained. In the range 20-79.0 sec the diphenyl ether content of the catalyzate remained practically constant, while the amount of aniline decreased somewhat.

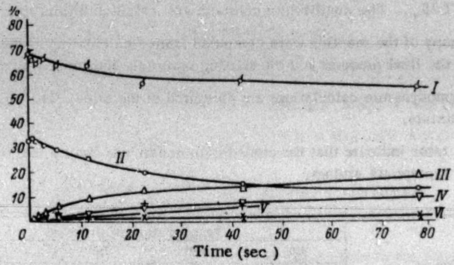


Fig. 2. Effect of time of contact on composition of catalyzate in alkylation of aniline by diphenyl ether on synthetic aluminosilicate at 500°. I) Diphenyl ether, II) aniline, III) diphenylamine, IV) phenol, V) water VI) ammonia.

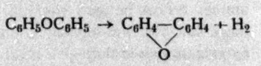
On the basis of the experiments conducted on the reaction of diphenyl ether with aniline, the formation of diphenylamine may be explained by the following reactions

$$C_6H_5OC_6H_5 + C_6H_5NH_2 \rightleftarrows C_6H_5NHC_6H_5 + C_6H_5OH \quad (1)$$

$$C_6H_5OH + C_6H_5NH_2 \rightleftarrows C_6H_5NHC_6H_5 + H_2O \quad (2)$$

$$C_6H_5NH_2 + C_6H_5NH_2 \rightleftarrows C_6H_5NHC_6H_5 + NH_3 \quad (3)$$

The formation of diphenylene oxide and benzene may proceed according to the reactions below, which have been confirmed by data in the literature [27, 28]. Benzene may also be obtained as a result of the deamination of aniline.



$$C_6H_5OC_6H_5 \rightarrow C_6H_4{-}C_6H_4 + H_2 \quad (4)$$

$$C_6H_5OC_6H_5 + H_2 \rightarrow C_6H_5OH + C_6H_6 \quad (5)$$

Experiments carried out with a whole series of materials under the conditions of the alkylation of aniline by diphenyl ether at 500° on synthetic aluminosilicate and 19-24 seconds contact time confirmed the possibility of processes (2 - 5). Thus, for example, phenol and aniline were converted to diphenylamine and water, and aniline to diphenylamine and ammonia. Diphenylamine in the presence of water yielded aniline and phenol. When diphenyl ether was passed over the catalyst, benzene and phenol were produced but it was not possible to separate diphenylene oxide from the catalyzate because of the small amounts of it; diphenyl ether and water yielded only phenol; phenol was partially converted to diphenyl ether.

In experiments with diphenyl ether and ammonia (1:3-1:4) in the range 450-600° the chief product was aniline (Fig. 3 and 4). The maximum conversion of diphenylether into aniline on synthetic alumino silicate occurred at 550° and amounted to 28.85 %; on active aluminum oxide it occurred at 500° (22%). Some diphenylamine, water, and phenol were formed along with the aniline. With a rise in temperature here, also, a considerable increase in side reactions was noted, leading to the formation of benzene and diphenylene oxide.

The production of aniline can be represented by the equations

$$C_6H_5OC_6H_5 + NH_3 \rightleftarrows C_6H_5NH_2 + C_6H_5OH \quad (6)$$

$$C_6H_5OH + NH_3 \rightleftarrows C_6H_5NH_2 + H_2O \quad (7)$$

The formation of dipheylamine may go according to reaction (2) or reaction (3).

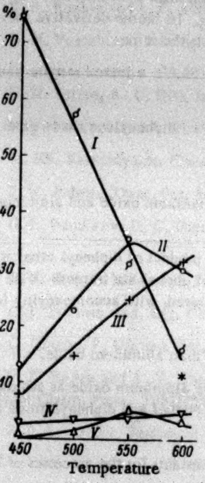


Fig. 3. Effect of temperature on composition of catalyzate in amination of diphenyl ether on synthetic aluminosilicate.
I) diphenyl ether, II) aniline, III) water, IV) phenol, V) diphenylamine.

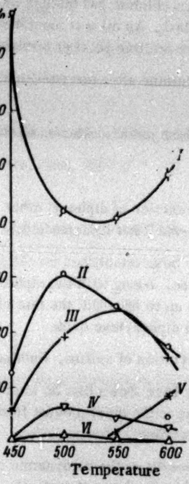


Fig. 4. Effect of temperature on composition of catalyzate in amination of diphenyl ether on active aluminum oxide.
I) diphenyl ether, II) aniline, III) water, IV) phenol, V) benzene, VI) diphenylamine.

EXPERIMENTAL

The reaction of diphenyl ether with aniline and ammonia was carried out in a circulating system. After each experiment, the catalyst was regenerated in a current of air at 500°.

The liquid catalyzate in the experiments on diphenyl ether with aniline was refluxed with 0.1N sulfuric acid solution to recover the dissolved ammonia, and then fractionally distilled on a column with an efficiency of 20 theoretical plates. The fraction containing a mixture of aniline and phenol was analyzed by diazotization and the bromide-bromate method, which permitted determination of the composition of the mixture without preliminary separation into its constituent parts. The amount of diphenylamine was determined by nitrosation [29]. The gaseous reaction products upon issuing from the contact tube passed through a system of traps filled with 0.1 N sulfuric acid to absorb the ammonia, and were collected in a gasometer and then analyzed in an Orsat apparatus.

In experiments on the amination of diphenyl ether, the catalyzate obtained was refluxed to remove ammonia and then fractionally distilled.

By fractional distillation of the catalyzates benzene, aniline (in experiments on the amination of diphenyl ether), phenol, diphenylamine, and diphenylene oxide were separated and identified.

The fraction that corresponded to benzene (b.p. 78-86° at 774 mm, n_D^{20} 1.5012, and setting point + 5.4°) was converted into dinitrobenzene (m.p. 88-89°, m.p. of mixed sample 89-90°).

In experiments with diphenyl ether and ammonia a fraction was separated with b.p. 179-183°, which after treatment with 10% NaOH solution was distilled from a Wurtz flask. The oil obtained (b.p. 182° at 759.2 mm,

d_4^{20} 1.021) gave an acetyl derivative with acetic anhydride with m.p. 113.5-114°, and a mixed sample with acetanilide gave no depression in melting point. Aniline hydrochloride was obtained from this fraction by passing hydrogen chloride gas through its ether solution. The ether solution after concentration was distilled from a Wurtz flask. An oil was separated which crystallized upon cooling. Its bromo derivative melted at 92-93°, and the melting point of a mixed sample with tribromophenol was the same.

Diphenylamine after recrystallization from alcohol melted at 51.5-52.0°; a mixed sample had the same melting point.

Diphenylene oxide melted at 82-83°, and a mixed sample with known diphenylene oxide gave no depression.

SUMMARY

1. The reaction of diphenyl ether with aniline and ammonia on aluminum oxide and aluminosilicate catalyst at 450-600° has been studied.

2. It has been established for the first time that the main reaction product of diphenyl ether with aniline is diphenylamine. Along with the diphenylamine considerable amounts of phenol are formed. With an increase in temperature up to 550-600° the rate of side reactions is greatly accelerated, with accompanying formation of benzene and diphenylene oxide.

In the arylation of aniline, aluminosilicate catalyst is more active than aluminum oxide.

3. It has been shown that on aluminosilicate catalyst and on active aluminum oxide at atmospheric pressure, aniline is the chief product from diphenyl ether and ammonia. Phenol and diphenylamine are obtained along with the aniline.

4. The results of thermodynamic calculation of the equilibrium constants for the processes of arylation of aniline with diphenyl ether and amination of diphenyl ether are presented.

5. Reaction schemes for diphenyl ether with aniline and with ammonia are given, which explain the experimental data.

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** In Russian.

REACTION OF β-CHLOROVINYL KETONES WITH β-DICARBONYL COMPOUNDS

IV. SYNTHESIS OF VINYLOGS OF ESTERS OF β-KETOACIDS

N.K. Kochetkov, L.I. Kudryashov, and R.A. Aleeva

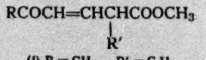
As reported earlier [1], when β-chlorovinyl ketones are reacted with alkylmalonic esters, the ketovinylation of the latter proceeds smoothly and alkyl-(3-ketoalkenyl) malonic esters $RCOCH = CHCR'(COOC_2H_5)_2$ are formed in high yields. The investigation of the chemical behavior of this new class of compounds, which are vinylogs of acylmalonic esters, is of substantial interest. The present work was devoted to the study of the cleavage of the alkyl-(3-ketoalkenyl) malonic esters by the action of alkaline agents. As is well known [2], acylmalonic esters under the influence of alcoholic solutions of alkalies in certain conditions undergo ketonic cleavage, as a result of which β-ketoesters are formed, and this reaction serves as a method for the synthesis of the latter compounds.

We have studied the behavior of the alkyl-(3-ketoalkenyl) malonic esters when they are reacted with a solution of potassium hydroxide in methanol. When the diethyl ester of ethyl-(3-ketobutenyl) malonic acid was treated with a large excess of methanol containing 3-4 moles of postassium hydroxide, even in the cold, potassium carbonate began to separate out and precipitated almost quantitatively; after a short period of heating and the usual treatment, a material was separated from the reaction mixture the analysis of which corresponded to the composition $C_9H_{14}O_3$, fitting the methyl ester of α-(ketobutenyl) butyric acid (I). The reaction is of a general character and other alkyl-(3-ketoalkenyl) malonic esters under similar conditions experience an analogous decomposition, forming the corresponding methyl esters of α-(3-ketoalkenyl) substituted fatty acids, which are previously unknown vinylogs of the esters of α-alkyl-β-ketoacids.

In carrying out the reaction it is necessary to use a large excess of methanol; otherwise the reaction mixture soon stratifies and the normal course of the reaction is disrupted. Substitution of sodium hydroxide for the potassium hydroxide does not give proper results. When the time of heating is increased, the reaction mixture undergoes much tar formation and, as a result, the yield of the product is sharply decreased, and it is considerably more difficult to isolate it in the pure state. (see formula below)

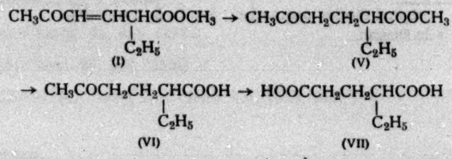
When the reaction conditions given in the experimental section of this paper are maintained, the yields of the reaction products are 50-90% and, thus, the conversion of alkyl-(3-ketoalkenyl) malonic esters investigated by us can serve as a convenient method for the synthesis of the previously unknown vinylogs of the esters of β-ketoacids.

Since the reaction of alkyl-(3-ketoalkenyl) malonic esters with alcoholic alkali can also follow other directions and in particular lead to certain pyrone derivatives, the structure of the compounds obtained by us required strict experimental proof. We confirmed the correctness of the structure assumed by us for the compounds prepared in the example of the ester of α-(3-ketobutenyl) butyric acid, converting it to ethylglutaric acid.



$$RCOCH{=}CH\underset{\displaystyle R'}{\underset{|}{C}}HCOOCH_3$$

(I) $R = CH_3$, $R' = C_2H_5$,
(II) $R = CH_3$, $R' = n\text{-}C_3H_7$,
(III) $R = C_2H_5$, $R' = n\text{-}C_3H_7$,
(IV) $R = C_7H_{15}$, $R' = n\text{-}C_3H_7$.



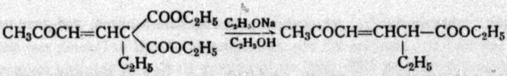
$$\underset{\text{(I)}}{CH_3COCH{=}CH\underset{\displaystyle C_2H_5}{\underset{|}{C}}HCOOCH_3} \rightarrow \underset{\text{(V)}}{CH_3COCH_2CH_2\underset{\displaystyle C_2H_5}{\underset{|}{C}}HCOOCH_3} \rightarrow$$

$$\rightarrow \underset{\text{(VI)}}{CH_3COCH_2CH_2\underset{\displaystyle C_2H_5}{\underset{|}{C}}HCOOH} \rightarrow \underset{\text{(VII)}}{HOOCCH_2CH_2\underset{\displaystyle C_2H_5}{\underset{|}{C}}HCOOH}$$

By hydrogenation of (I) over palladium on barium sulfate the methyl ester of α-ethyl- γ-acetylmalonic acid (V) was obtained, the melting point of the semicarbazone of which agreed with that given in the literature. By saponification of (V) the corresponding acid (VI) was obtained, also identified by the known semicarbazone. Finally, (VI) was converted by oxidation with hypobromite to α-ethylglutaric acid (VII), which was identified as its bis-benzylthiuronium salt. This conversion left no doubt that the structure proposed by us for the decomposition products of alkyl-(3-ketoalkenyl)malonic esters was correct.

As we have mentioned, the analysis of the materials obtained by us corresponds to the methyl esters of α-(3-ketoalkenyl) fatty acids. This circumstance can be explained by the fact that the decomposition of the alkyl-(3-ketoalkenyl) malonic esters is accompanied by simultaneous transesterification of the carboethoxy groups retained in the molecule. It is well known that transesterification of carboalkoxy groups takes place readily with a large excess of alcohol in the presence of an alkaline agent; this reaction is known both for malonic ester [3] and for esters of β-ketoacids [4]. Our reaction conditions were completely favorable for the transesterification process. It must be noted that the reaction products apparently contained a small admixture of the appropriate ethyl esters of α-(3-ketoalkenyl) fatty acids, as indicated by the data from the analysis of the imperfectly purified reaction products, and consequently the transesterification process did not proceed quantitatively. However, the isolation of the pure methyl esters was not difficult and was accomplished by simple distillation.

We tried to eliminate the complicating transesterification process by carrying out the cleavage of the alkyl-(3-ketoalkenyl) malonic esters in ethyl alcohol. However, attempts to replace the methyl alcohol with ethyl did not give advantageous results, since in this case the formation of a precipitate of potassium carbonate lead to stratification of the reaction mixture with separation of an aqueous phase that upset the normal course of the process. Positive results were obtained by treating the ethyl-(3-ketobutenyl) malonic ester with a solution of sodium ethylate in ethyl alcohol at room temperature. Contrary to our expectations, we did not observe in this case any condensation processes, and the reaction went smoothly with a 58% yield of ethyl ester of α-(3-ketobutenyl) butyric acid.



$$CH_3COCH{=}CH\underset{\displaystyle C_2H_5}{C}\begin{matrix}COOC_2H_5\\COOC_2H_5\end{matrix} \xrightarrow[C_2H_5OH]{C_2H_5ONa} CH_3COCH{=}CH\underset{\displaystyle C_2H_5}{CH}{-}COOC_2H_5$$

This modification of the reaction, which we have as yet carried out only in this single example may prove further to be more expedient.

The decomposition reaction of alkyl-(3-ketoalkenyl) malonic esters investigated by us is wholly analogous in its course to the known breakdown of acylmalonic esters [2]. It presents a new, clear illustration of the principle of vinylogy. Investigation of the chemical behavior of the representatives of the previously unknown class of vinylogs of β-ketoesters that we have prepared is of great interest.

EXPERIMENTAL

Methyl ester of α-(3-ketobutenyl) butyric acid (I). A solution of 26.5 g (0.47 mole) of potassium hydroxide in the minimum amount of water was mixed with 500 ml of methanol, 30.3 g (0.12 mole) of the diethyl ester of ethyl-(3-ketobutenyl) malonic acid was added, and the mixture was heated with a reflux condenser to slight boiling on a water bath for 30 minutes. The mixture acquired a reddish color and a crystalline precipitate of potassium carbonate separated out. The mixture was cooled for 1 hour, the precipitate was filtered off and washed with methyl alcohol, and about 400 ml of methanol was distilled off from the mother liquor in vacuo with a water pump. The residue was diluted with 200 ml of water, sufficient 10% hydrochloric acid was added to give an acid reaction to litmus (about 70 ml), and the oil that separated was extracted with ether. The extract was dried over magnesium sulfate, the ether was distilled off, and the residue was distilled in vacuo and yielded 12.8 g

(63%) of a substance with b.p. 104-107° (6 mm), n_D^{20} 1.4625.

After two distillations the material had the following constants:

b.p. 122-123° (9 mm), 109-110° (7 mm), 104-105° (6 mm), 88-89° (4 mm), n_D^{20} 1.4624, d_4^{20} 1.0210, MR_D 45.86; calc. 44.96.

Found %: C 63.63, 63.75; H 8.18, 8.28. $C_9H_{14}O_3$.
Calculated %: C 63.51; H 8.29.

The methyl ester of α-(3-ketobutenyl) butyric acid was a yellowish liquid, stable on storage, miscible with organic solvents, insoluble in water, soluble in concentrated alkali solution. It decolorized permanganate solution; it did not give a color with ferric chloride, but in alcohol-benzene solution a deepening of the color was observed.

ethyl ester of α-(3-ketobutenyl) valeric acid(II) was prepared in a manner similar to the preceding compound from 9.7 g of the diethyl ester of propyl-(3-ketobutenyl) malonic acid and 8.1 g of potassium hydroxide in 150 ml of methanol. Upon distillation, 4 g (60%) was obtained of a material with b.p. 101-108° (4 mm), n_D^{20} 1.4618. After two distillations the material had the following constants:

b.p. 105-106° (5 mm), n_D^{20} 1.4605, d_4^{20} 1.0033, MR_D 50.33; calc. 49.58.

Found % C 65.63, 65.48; H 8.80, 8.90. $C_{10}H_{16}O_3$.
Calculated %: C 65.19; H 8.75.

The slightly yellowish liquid was stable on storage, decolorized permanganate, and did not give a color with ferric chloride.

Methyl ester of α-(3-ketopentenyl) valeric acid (III) was prepared in a similar manner from 12 g of the diethyl ester of propyl-(3-ketopenten-1-yl) malonic acid and 9.52 g of potassium hydroxide in 180 ml of methanol. Upon distillation, 7.6 g (91.5%) was obtained of a substance with b.p. 118-120° (5 mm). After repeated distillation the material had the following constants:

b.p. 111-112° (4 mm), n_D^{20} 1.4683, d_4^{20} 0.9944, MR_D 55.45; calc. 54.20.

Found %: C 66.50, 66.62; H 9.08, 9.11. $C_{11}H_{18}O_3$.
Calculated: C 66.64; H 9.15.

The colorless liquid, stable on storage, decolorized permanganate solution, and gave no color with ferric chloride.

Methyl ester of α-(3-ketodecen-1-yl) valeric acid (IV) was prepared similarly from 5 g of the diethyl ester of propyl-(3-ketodecen-1-yl)- malonic acid and 3.14 g of potassium hydroxide in 55 ml of methanol. Upon distillation, 2.4 g (64%) was obtained of a substance with b.p. 163-166° (5-5.5 mm). After repeated distillation the material had the following constants:

b.p. 134-136° (0.3 mm), n_D^{20} 1.4638, d_4^{20} 0.9518, MR_D 77.82; calc. 77.29.

Found %: C 71.87, 71.79; H 10.54, 10.56. $C_{16}H_{28}O_3$.
Calculated %: C 71.60; H 10.51.

The slightly yellowish liquid, stable on storage, decolorized permanganate solution, and gave no color with ferric chloride.

Methyl ester of α-ethyl-γ-acetylbutyric acid (V). 9.7 g of freshly distilled ester (I) was hydrogenated at room temperature in 50 ml of alcohol over 0.1 g of palladium on barium sulfate (palladium content 5%). A total of 1560 ml of hydrogen was absorbed (calculated requirement 1280 ml). After the usual treatment and distillation, 9 g (92%) was obtained of a substance with b.p. 91-96° (4-5 mm), n_D^{20} 1.4341. After repeated distillation the material had the following constants:

b.p. 91-92° (4 mm), n_D^{20} 1.4360, d_4^{20} 0.9833, MR_D 45.79; calc. 45.43.

Found % C 63.15, 63.14; H 9.45, 9.50. $C_9H_{16}O_3$.
Calculated %: C 62.76; H 9.36.

Literature data for the methyl ester of α-ethyl-γ-acetylbutyric acid [5]: b.p. 75° (2 mm).

The semicarbazone prepared by the method described in [5] formed colorless crystals with m.p. 110.5-111° (from 30% aqueous alcohol).

Found %: N 18.26, 18.53. $C_{10}H_{19}O_3N_3$.
Calculated %: N 18.33.

Literature data [5]: m.p. 108°.

α-Ethyl-γ-acetylbutyric acid (VI). 14 g of material from the preceding experiment was boiled with a solution of 12.8 g of sodium hydroxide in 50 ml of water for 2.5 hours until the oil completely dissolved. The cooled solution was made acid to litmus with 10% hydrochloric acid (about 35 ml), the oil that separated was extracted with ether, the extracts were dried over sodium sulfate, the ether was distilled off, and the residue was distilled in vacuo. 8.5 g (78%) of a substance was obtained with b.p. 147° (7 mm), n_D^{20} 1.4483. Literature data for α-ethyl-γ-acetylbutyric acid: b.p. 135-137° (2 mm) [5], 158° (9 mm) [6].

A semicarbazone was prepared by the usual method: colorless crystals with m.p. 131-131.5° (from 30% aqueous alcohol).

Found %: N 19.31, 19.42. $C_9H_{17}O_3N_3$.
Calculated %: N 19.52.

Literature data [5]: m.p. 127-129°.

α-Ethylglutaric acid (VII). In a flask fitted with a stirrer, thermometer, and dropping funnel was placed 18.8 g of sodium hydroxide in 160 ml of water, and 22.5 g of bromine was added at 0-3°. To the solution obtained was added gradually 7.5 g of α-ethyl-γ-acetylbutyric acid from the preceding experiment at such a rate that the temperature of the reaction mixture did not exceed 5°. When the addition was completed, the mixture was wholly decolorized; it was stirred for 2 hours more at 18-20°, extracted with ether, the water layer was acidified to litmus with concentrated sulfuric acid, the oil that separated was extracted with ether, the extracts were dried over sodium sulfate, the ether was distilled off, and the residue was distilled and fraction collected with b.p. 174-175° (3 mm). After standing in a vacuum desiccator over phosphorus pentoxide the material crystallized to a mass with m.p. 49-51°. Literature data for α-ethylglutaric acid: b.p. 150° (0.3 mm), m.p. 59-60° [7]; b.p. 175° (11 mm), m.p. 54° [8].

Bis-benzylthiuronium salt. To a solution of 0.30 g of material in 1 ml of water, solid sodium hydroxide was added until the reaction was neutral to litmus (about 0.15 g), and the solution obtained was poured into a solution of 0.62 g of benzylthiuronium chloride in a small amount of alcohol. The mixture was evaporated to dryness, the residue was dissolved in anhydrous alcohol, the insoluble residue was filtered off, and by adding absolute ether the bis-benzylthiuronium salt was precipitated from the filtrate as colorless crystals with m.p. 134-135°. A mixed sample with known bis-benzylthiouronium salt of α-ethylglutaric acid gave no depression in melting point.

Found %: N 11.37. $C_{23}H_{32}O_4N_4S_2$.
Calculated %: N 11.37.

Literature data [7]: m.p. 131.5-132°.

Ethyl ester of α-(3-ketobutenyl) butyric acid. To a solution of 4.8 g (0.20 g-atom) of sodium in 100 ml of anhydrous alcohol was gradually added, with stirring, 12 g (0.047 mole) of the diethyl ester of ethyl-(3-ketobutenyl) malonic acid. The mixture warmed up and took on a red color. When the addition of the ketobutenylmalonic ester was completed, it was left over night at room temperature. Then 200 ml of water was added, part of the alcohol (about 90 ml) was distilled off in vacuo with a water pump, the precipitate was filtered off, the residue was distilled in vacuo, and a fraction was collected with b.p. 112-116° (9 mm). Yield 5.0 g (58%). After repeated distillation the material had the following constants:

b.p. 93-94° (3 mm), n_D^{20} 1.4630, d_4^{20} 1.0000, MR_D 50.74; calc. 49.58.

Found %: C 65.57, 65.54; H 8.63, 8.61. $C_{10}H_{16}O_3$.
Calculated %: C 65.19; H 8.75.

The slightly yellowish oil, stable on storage, decolorized permanganate solution, and gave no color with ferric chloride.

SUMMARY

1. It has been shown that by treatment of the diethyl esters of alkyl-(3 ketoalkenyl) malonic acid with a solution of potassium hydroxide in methanol, the methyl esters of α-(3-ketoalkenyl) fatty acids are formed. This reaction can serve as a general method for the synthesis of these compounds, which are previously unknown vinylogs of the esters of β-ketoacids.

2. The structure of the compounds prepared was demonstrated by the example of the conversion of the methyl ester of α-(3-ketobutenyl)-butyric acid by successive hydrogenation, saponification, and oxidation to α-ethylglutaric acid.

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INVESTIGATIONS IN THE FIELD OF POLYCYCLIC COMPOUNDS

XIV.* THE SYNTHESIS OF ANTHRAQUINONE-1-ARSONIC AND -1-PHOSPHONIC ACIDS BY THE DIAZO METHOD

A.M. Lukin and G.S. Petrova

In preparing phenylarsonic acids according to Bart's method, it is recommended that the rather unstable chlorides and sulfates of the starting diazo compound be replaced by the stable fluoborates, the use of which in most cases increases the yields of the corresponding arsonic acids(see [1] and [2-7]). However, it has not been accurately established whether this increase in yield is, as the authors affirm, a result of the greater stability of the diazofluoborates or whether the chemical nature of the anion of the diazonium salt also plays a role here. To clarify this question we carried out the synthesis of anthraquinone-1-arsonic acid under the conditions described in the literature ([8], see also [9]) from the following almost equally stable diazo compounds of α-aminoanthraquinone: the chloride, sulfate, and fluoborate. Of these compounds, the first two have been described previously [10,11]; the last-named was prepared by us for the first time according to the method in [12], but using a double excess of nitrite.

Our experiments showed that the nature of the anion of the starting diazonium compounds very greatly influenced the yield of the final acid in comparison with their stability, and the best results were given in our case by the diazonium sulfate. A similar effect of the composition of the diazonium salts was established by us in the case of the synthesis of the already described anthraquinone-1-phosphonic acid; the latter synthesis was carried out under conditions suggested by Doak and Freedman [13]. In this case the effect of the composition of the starting compounds played a more significant role, and the best results were obtained by us with the diazonium fluoborate (see table).

Dependence of the Yield of Anthraquinone-1-Arsonic and -1-Phosphonic Acids on the Nature of the Anion of the Starting Diazo Compound

Starting diazonium salt		Yield (in %)	
Name	Amount (in g 100% of materal)	anthraquinone-1-arsonic acid	anthraquinone-1-phosphonic acid
Sulfate	7.1	65	—
	14.25	—	6.6
Chloride	7.4	17.5	—
	9.5	—	9.9
Fluoborate	6.9	23	—
	14.1	—	60

Thus, our data indicate that in syntheses of arsonic and phosphonic acids by the diazo method not only the stability of the starting diazo compounds but also the nature of their anions has a great influence on the yield of the end compounds.

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* For a previous communication of this series see: J. Gen. Chem., 20, 2219 (1950) [See C. B. translation].

Besides the free anthraquinone-1-phosphonic acid, we also prepared two of its salts – the monosodium and monoammonium (see experimental section).

Since the phenylphosphonic, phenylarsonic, and anthraquinone-1-arsonic acids had already been described as analytical reagents for certain cations, for example, first for thorium [14] (the authors used this method for the gravimetric determination of quantities above 0.02 g) and later for tin [8], it could be assumed that the newly synthesized anthraquinone-1-phosphonic acid might also prove to be reactive toward cations. Investigation of its properties and particulary the properties of the above-mentioned salts verified our assumption: the ammonium salt, used because it was more, soluble, was a good precipitant for thorium. The most favorable medium for the precipitation of thorium was acetate buffer with pH 3.5-4.4. (It was established experimentally that precipitation at pH 7 did not ensure complete deposition; precipitation at pH 2.6 was hampered because of the separating out of the reagent itself in the precipitate). The sensitivity of the reaction at pH 3.5-4.4 was 10 γ Th in 5 ml (4.5 ml of acetate buffer, 0.5 ml 0.5% aqueous solution of reagent + 10 γ Th*). We have not investigated the relationship of the compound in question to other cations.

EXPERIMENTAL

Synthesis of diazonium fluoborate from α-aminoanthraquinone. 11.8 g 95% of α-aminoanthraquinone was reprecipitated from concentrated sulfuric acid and to the paste thus obtained was added 100 ml of 40% hydrofluoboric acid, after which the suspension obtained was diazotized at 35-40° with 40% aqueous solution of sodium nitrite (7 g $NaNO_2$). When the diazotization was completed, the reaction mixture was cooled to 0°, the precipitate diazonium fluoborate was filtered out, washed twice with 50 ml of ether, and dried in air. 15.5 g of a light brown, crystalline powder was obtained. The material contained 9% of undiazotized α-aminoanthraquinone. Consequently, the yield of diazonium was 87.5% of theoretical. Given below are the results of the analysis of the diazonium fluoborate recrystallized twice from boiling water.

Found %: N 8.54, 8.58. $C_{14}H_7O_2N_2BF_4$.
Calculated %: N 8.70.

Synthesis of anthraquinone-1-phosphonic acid. To a mixture of 80 ml of absolute ethyl acetate and 8.4 ml (0.096 g-mole) of phosphorus trichloride at room temperature was added in small portions a mixture of 15.5 g (0.044 g-mole) of the diazonium fluoborate from α-aminoanthraquinone and 1 g of cuprous bromide. Usually when the diazonium compound was introduced the evolution of gas began; otherwise the temperature of the reaction mixture was gradually raised to 60°. Upon this elevation of the temperature, the evolution of gas always proceeded with a simultaneous change in the color of the solution from light yellow to dark brown. The reaction solution was stirred further for 2 hours at 60-65°. The next day 12 ml of water was added to the reaction mixture dropwise, while stirring, at 20-30°, the mixture was stirred for 1 hour, and then the ethyl acetate was steam-distilled off from the product. The precipitate that formed was filtered off, washed with 50 ml of water, transferred to 400 ml of 5% sodium hydroxide solution, 7 g of activated carbon was added, the mixture was heated to boiling, and then the hot solution was again filtered and the filtrate was acidified with concentrated nitric acid. Free anthraquinone-1-phosphonic acid thereupon precipitated, which was filtered off after cooling the mixture, then washed with 100 ml of distilled water and dried at 100°. 7.6 g of a yellow powder was obtained, amounting to 60% calculated on the basis of the diazonium fluoborate.

Upon crystallization from dilute (1:1) nitric acid with carbon, a light yellow, finely crystalline powder was obtained, almost insoluble in water but soluble in alkali solutions, then taking on a yellow color. The acid was difficultly soluble in most organic solvents; it melted above 300°.

Found %: P 10.85, 11.06. $C_{14}H_9O_5P$.
Calculated %: P 10.75.

Synthesis of sodium and ammonium salts of anthraquinone-1-phosphonic acid. The above-mentioned salts of anthraquinone-1-phosphonic acid were preapared by dissolving it by heating to boiling either in 1 N sodium hydroxide solution (proportion 1 g: 5 ml) or in 20% ammonia solution (proportion 1 g: 50 ml), filtering the hot solution, and cooling the filtrate. The salts that precipitated upon this treatment were filtered out, washed with water once, and dried at 100°. Both salts were obtained as light yellow powders, readily soluble in water.

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* Conditions for the use of the ammonium salt of anthraquinone-1-phosphonic acid as a reagent were established by G. G. Karanovich.

Found %: P 9.92, 9.62. $C_{14}H_8O_5PNa$. Calculated %: P 9.98.
Found %: N 4.88, 4.76. $C_{14}H_{12}O_5NP$. Calculated %: N 4.59.

SUMMARY

1. The first representative of the phosphonic acids of the anthraquinone series has been prepared – anthraquinone-1-phosphonic acid and two of its salts – the monosodium and monoammonium.

2. It has been established that the nature of the anion of the starting diazonium salts has a considerable effect on the formation of the anthraquinone-1-phosphonic acid by the method of Doak and Freedman and on the synthesis of anthraquinone-1-arsonic acid by the method of Bart.

3. It has been established that the ammonium salt of anthraquinone-1-phosphonic acid is a good precipitant for thorium.

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REACTION OF 9,10-DIHALOANTHRACENE WITH ARYL SULFONAMIDES

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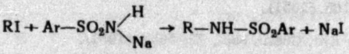
Many investigators have studied the exchange of active halogen in aromatic compounds on different groups, in particular those containing the sulfonamide group. From α-haloanthraquinones and aryl sulfonamide derivatives from which various mono- and diamino derivatives of anthraquinone have been prepared [1-3]. The problem of the exchange of halogens on other atomic groupings in meso-haloanthracenes has scarcely been studied at all. Taking advantage of the mobility of the halogen atoms in 9,10-dichloroanthracene, it has been possible to make an exchange for the sulfo group by heating 9,10-dichloroanthracene in sodium sulfite [4]. B. P. Fedorov and E. I. Sheludyakova [5] prepared the salt of 2,9,10-anthracenetrisulfonic acid by heating the salt of 9,10-dichloroanthracene-2-sulfonic acid with an aqueous solution of sodium sulfite.

The capacity for easy exchange of the halogens in meso-dihaloanthracene permitted the assumption that, as in the case of the action of the aryl sulfamides on the haloanthracenes, it might be possible to prepare the corresponding arylsulfonamido substitution products of anthracene. The methods of preparation and the properties of such N-arylsulfonamido substitution products of anthracene have not been described in the literature and would no doubt be of interest. The preparation of the N-substituted sulfonamides from aromatic compounds with labile halogens and an aryl sulfonamide can be carried out, basically, by the following two methods: 1) by heating the halosubstituted compounds with the aryl sulfonamides in various solvents, in the presence of copper as a catalyst [6]; 2) by an exchange reaction of the salts of aryl sulfonamides with the halogen-substituted compounds [7].

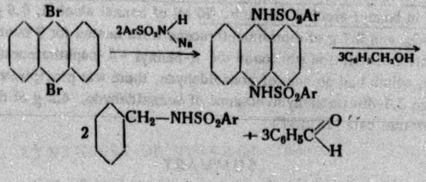


$$RI + Ar{-}SO_2N\begin{smallmatrix}H\\ Na\end{smallmatrix} \rightarrow R{-}NH{-}SO_2Ar + NaI$$

The latter method, using benzyl alcohol as solvent, was chosen for the investigation of the reaction of 9,10-dihaloanthracene with aryl sulfonamides. However, as a result of the reaction with benzenesulfonamide, N-benzylbenzenesulfonamide was obtained; this permitted the deduction that the reaction of 9,10-dibromoanthracene with benzenesulfonamide in benzyl alcohol as solvent is accompanied by an oxidation-reduction reaction which leads to the rupture of the unstable, central ring of anthracene and the formation from 1 mole of dihaloanthracene of 2 moles of N-benzylbenzenesulfonamide.

Thus when 9,10-dibromoanthracene was reacted with p-toluenesulfonamide and with β-naphthalenesulfonamide, the benzyl derivatives of the appropriate sulfonamides were obtained and it became obvious that this reaction is a general one. Quantitative separation of sodium chloride or bromide from the reaction products indicated an exchange conversion in one of the stages. With regard to oxidation-reduction processes, they were demonstrated by the formation of benzaldehyde, which could be produced only as a result of oxidation of a part of the benzyl alcohol, and also by the almost quantitative production of N-benzylarylsulfonamides. The benzaldehyde was determined quantitatively and it was established that almost 3 moles of benzaldehyde (90 %) was obtained from 1 mole of dibromoanthracene and 2 moles of the sodium salt of the arylsulfonamide in excess benzyl alcohol.

The results obtained permitted the assumption that the reaction under investigation can be represented by the following scheme



In the first stage an exchange reaction occurs with the formation of 9,10-diarylsulfonamido-substituted anthracenes, which are further converted as a result of oxidation–reduction processes to N-benzylaryl-sulfonamides and benzaldehyde.

9,10-Dichloroanthracene undergoes a similar reaction with aryl sulfonamides, but with considerably less speed.

The new reaction described can be used to establish the structure of a series of substituted anthracenes and for the synthesis of new sulfonamido-compounds.

EXPERIMENTAL

The starting materials had the following constants: benzyl alcohol, b.p. 204-207°; dibromoanthracene, prepared by the bromination of anthracene in carbon tetrachloride solution [8], m.p. 221-222°; benzenesulfonamide, m.p. 213-214°.

Reaction of 9,10-dibromoanthracene with arylsulfonamides. In a three-necked flask with a mechanical stirrer, reflux condenser, and thermometer was placed 150 ml of benzyl alcohol and 1.2 g (0.05 mole) of metallic sodium was added, the amount necessary to replace with sodium only one hydrogen in the arylsulfonamide. Then to the alcoholate solution obtained were added 7.5 g (0.048 mole) of benzenesulfonamide and 5.4 g (0.016 mole) of dibromoanthracene. The reaction mixture was heated, with careful stirring, for 9 hours at the boiling point of benzyl alcohol. In the process of heating, the solution took on a brown-red color. When it was cooled, a precipitate separated – sodium bromide with a small admixture of unreacted, excess benzenesulfonamide. After the precipitate had been filtered off, the benzyl alcohol was distilled off in vacuo from the reaction solution. The residue after distillation of the alcohol solidified upon cooling as a thick, brown mass. After recrystallization of the product from a mixture of benzene and petroleum ether, 5.9 g of N-benzylbenzenesulfonamide was obtained. This was a white, lustrous powder, m.p. 83-84°, readily soluble in alcohol and ether, difficultly soluble in petroleum ether.

According to data in the literature [9]: m.p. 85°.

Found %: N 5.91. M 239. $C_{13}H_{13}O_2NS$.
Calculated %: N 5.66 M 247.

The reaction with p-toluenesulfonamide was carried out similarly. 7.5 g of N-benzyl-p-toluenesulfonamide was obtained: white, lustrous powder, when twice recrystallized from a mixture of benzene and petroleum ether m.p. 113-114°.

According to data in the literature [9]: m.p. 116°.

Found %: N 5.66. M 255. $C_{14}H_{15}O_2NS$.
Calculated %: N 5.32 M 260.3.

When 9,10-dibromoanthracene was reacted with β-naphthalenesulfonamide, 9.4 g of N-benzyl-β-naphthalenesulfonamide was obtained. White, slightly yellowish crystals with m.p. 120-121°.

According to data in the literature [9]: m.p. 124°.

Found %: N 4.92. M 294. $C_{17}H_{15}O_2NS$.
Calculated %: N 4.70. M 297.3.

In all experiments N-benzylarylsulfonamides were obtained in yields of 75-85%.

Determination of the amount of benzaldehyde obtained in the reaction of 9,10-dibromoanthracene with β-naphthalenesulfonamide in benzyl alcohol medium. 75 ml of benzyl alcohol, 0.6 g of metallic sodium, 5 g of β-naphthalenesulfonamide, and 2.7 g of dibromoanthracene were heated for 9 hours, as in the preceding experiments. In the residue after distillation was found the N-benzyl-β-naphthalenesulfonamide described above. From the aqueous distillate, which had an odor of benzaldehyde, there was precipitated with 2,4-dinitrophenylhydrazine solution an orange 2,4-dinitrophenylhydrazone of benzaldehyde. 4.5 g of this compound was obtained (90%), m.p. 236-237° (literature data [10]:237°).

SUMMARY

1. The reaction of dihaloanthracenes with aryl sulfonamides in benzyl alcohol solution is accompanied by an oxidation-reduction reaction, in which the benzyl derivative of the arylsulfonamide is formed.

2. The reaction investigated can be used to introduce benzyl radicals into various arylsulfonamides.

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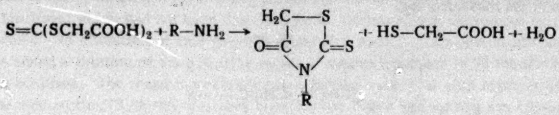
* Russian translation.

SYNTHESIS OF THIAZOLE DERIVATIVES.

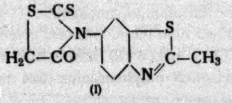
XII. BENZOTHIAZOLYLRHODANINES.

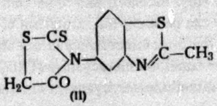
V.M. Zubarovsky and T.M. Verbovskaya

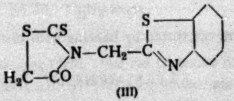
Derivatives of rhodanine (2-oxothiazolidine-4-thione) containing substituents on the nitrogen atom are used considerably for the synthesis of polymethine dye-photosensitizers. For this reason the preparation of new N-substituted rhodanines deserves attention. The purpose of the present work was the synthesis of isomeric N-benzothiazolylrhodanines undescribed in the literature and some of their characteristic derivatives. One of the methods of preparing N-substituted rhodanines was used which consists in the condensation of thiocarbonyl-bis-thioglycolic acid with primary amines.



2-Methyl-6-amino-, 2-methyl-5-amino-, and 2-aminomethylbenzothaizoles were used as amines. The condensation was carried out by the gradual addition of an alcohol – water solution of the amine to an aqueous solution of the sodium salt of thiocarbonyl-bis-thioglycolic acid. In all instances, along with the benzothiazolylrhodanine there was formed more or less of the symmetrical dibenzothiazolylthiourea. However, if a considerable excess of thiocarbonyl-bis-thioglycolic acid was used and the amine was gradually introduced into the reaction, the contaminating thiourea was sharply reduced and the rhodanines synthesized were easily freed from it. The benzothiazolylrhodanines (I-III) prepared were pale yellow, crystalline substances of a weakly basic character;

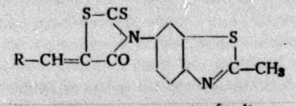

(I)


(II)

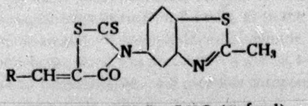

(III)

they did not dissolve in the cold in 15% hydrochloric acid, were difficultly soluble in it on heating, dissolved in concentrated hydrochloric acid, but precipitated upon dilution with water. The benzothiazolylrhodanines were not soluble in dilute or concentrated solutions of alkalies, and when heated with concentrated alkalies they decomposed.

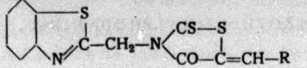
The benzothiazolylrhodanines condense easily, as a result of the methylene group in the rhodanine ring with aldehydes of the aromatic and heterocyclic series. For each of the benzothiazolylrhodanines described, condensation products were obtained with benzaldehyde, furfural, and α-thiophenaldehyde.



(IV) R = C_6H_5; (V) R = C_4H_3O(α-furyl)
(VI) R = C_4H_3(α-thienyl)



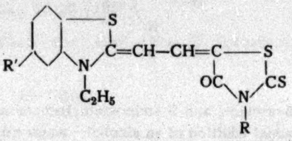
(VII) R = C_6H_5; (VIII) R = C_4H_3O (α-furyl)
(IX) R = C_4H_3 (α-thienyl)



(X) R = C_6H_5; (XI) R = C_4H_3O(α-furyl) (XII) R = C_4H_3 (α-thienyl)

The condensation products of the benzothiazolylrhodanines (I-III) with aldehydes were pale yellow, yellow, or orange-yellow, finely crystalline, high-melting substances. With the heterocyclic aldehydes more deeply colored products were obtained than with benzaldehyde. Upon heating with an excess of dimethyl sulfate, substances (IV-XII) were converted to quaternary salts, which reacted both with p-dimethylaminobenzaldehyde and with the p-toluenesulfonate of 2-methylbenzothiazole to form dyes. The structure of these salts has not yet been investigated.

The benzothiazolylrhodanines (I-III) upon heating in pyridine with the iodoethylate of 2-(ω-acetanilinovinyl) benzothiazole or its methoxy derivative formed dyes – dimethinemerocyanines, containing a benzothiazole group on the nitrogen atom of the rhodanine ring.



(XIII) R = 2-methyl-benzthiazolyl-6-, R' = H; (XIV) R = 2-methyl-benzthiazolyl-6-, R' = OCH_3;
(XV) R = 2-methyl-benzthiazolyl-5-, R' = H; (XVI) R = 2-methyl-benzthiazolyl-5-, R' = OCH_3;
(XVII) R = benzthiazolyl-2-methyl-, R' = H; (XVIII) R = benzthiazolyl-2-methyl-, R' = OCH_3.

The merocyanines (XIII-XVIII) formed high-melting red or brown-red crystals with a violet or greenish luster. The merocyanines that did not contain methoxy groups (XIII), (XV), and (XVII) had the same absorption maximum at 528 mμ (in ethyl alcohol), and those containing a methoxy group (XIV), (XVI), and (XVIII) had a maximum at 535 mμ. As can be seen, the isomerism of the benzothiazolylrhodanines (I-III) is not expressed in the absorption maxima of the dimethinemerocyanines obtained from them. We also noted that the absorption maximum (528 mμ) of the dimethinemerocyanines (XIII), (XV), and (XVII) differs little from the absorption maxima of the analogous dimethinemerocyanines obtained from N-ethylrhodanine (524 mμ) and N-phenylrhodanine (526 mμ).

The merocyanines (XIII-XVIII) were converted by heating with dimethyl sulfate to quaternary salts.

EXPERIMENTAL

Synthesis of Benzothiazolylrhodanines.

N-(2' Methylbenzothiazolyl-6')-rhodanine (I). The thiocarbonyl-bis-thioglycolic acid necessary for this synthesis was prepared by the method of Holmberg [1]. In a three-necked flask fitted with a reflux condenser, mechanical stirrer, and dropping funnel* was placed 67.8 g (0.3 mole) of thiocarbonyl-bis-thioglycolic acid, 1200 ml of water was added, and then a solution of 15.9 g (0.15 mole) of anhydrous sodium carbonate in 300 ml of water was added while the mixture was stirred and heated on a boiling water bath. To the solution of half-neutralized thiocarbonyl-bis-thioglycolic acid was added drop by drop, with stirring, over a period of 3 hours, a solution of 16.4 g (0.1 mole) of 2-methyl-6-aminobenzothiazole in 200 ml of aqueous alcohol (1:1). A yellow precipitate quickly appeared. The mixture was stirred and heated for another 30 minutes and left for 12-15 hours. The precipitate was filtered out, triturated with an excess of 15% sodium carbonate solution, filtered off, and washed with water. The yield of crude rhodanine, which contained as a contaminant symmetrical bis-(2-methylbenzothiazolyl-6)-thiourea, was 24 g. The crude product was dissolved in 150 ml of chloroform, the insoluble thiourea was filtered off, the chloroform was completely distilled off from the filtrate, the residue was refluxed with 20 ml of ethyl alcohol, the hot mixture was filtered, and the residue was washed on the filter with 20 ml of alcohol and ether until the filtrate appeared colorless. The yield of rhodanine was 14.0-17.0 g (50-60.7%). The compound was a pale yellow, finely crystalline powder with m.p. 195-200°. For most of the work it was not necessary to further purify the rhodanine. For analysis, the rhodanine was twice crystallized from ethyl alcohol (with carbon) and obtained with m.p. 202°.

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* It was necessary to carry out the reaction under draft and to trap the thioglycolic acid that was given off.

Found %: N 10.09, 10.17. $C_{11}H_8ON_2S_3$.
Calculated %: N 10.00.

With this method of preparing the rhodanine (I) the admixture of the thiourea mentioned above was not large. However, when the amount of thiocarbonyl-bis-thioglycolic acid and the time of adding the 2-methyl-6-aminobenzothiazole were decreased, the amount of thiourea increased considerably. In one of the experiments the thiourea was separated, purified by crystallization from ethyl alcohol, and identified by comparison with symmetrical bis(2-methylbenzothiazolyl-6)-thiourea prepared in the usual way for the synthesis of symmetrical diarylthioureas – from 2-methyl-6-aminobenzothiazole and carbon bisulfide. Both preparations and a mixture of them melted at 180°.

The synthesis of the symmetrical bis(2-methylbenzothiazole-6)-thiourea from 2-methyl-6-aminobenzothiazole and carbon bisulfide, which had not been described in the literature, was carried out by I. K. Ushenko in the following manner: to a solution of 12.3 g (0.075 mole) of 2-methyl-6-aminobenzothiazole in 36 ml of ethyl alcohol was added a solution of 1.5 g (0.0375 mole) of sodium hydroxide in 36 ml of water and 2.85 g (2.4 ml) of carbon bisulfide. The mixture was heated on a boiling water bath with vigorous, periodic shaking. In 10 minutes a second portion (2.85 ml) of carbon bisulfide was added and heating was continued for 15 minutes more. Finally, there was added to the hot solution over a period of 30 minutes 30 ml of 40% sodium bisulfite solution. After cooling, the white precipitate was filtered off and repeatedly washed with water. The yield of the thiourea was 13.2 g (96%). The material was purified by crystallization from a large amount of ethyl alcohol. The melting point after two crystallizations was 180°.

Found %: N 15.20, 15.18. $C_{17}H_{14}N_4S_3$.
Calculated %: N 15.13.

N-(2'-Methylbenzothiazolyl-5')rhodanine (II). Rhodanine (II) was prepared from 16.4 g of 2-methyl-5-aminobenzothiazole and 67.8 g of thiocarbonyl-bis-thioglycolic acid. The method of synthesis did not differ at all from the method of preparing (I). The yield of crude rhodanine (II) was 22.0 g. To separate out the contaminating benzothiazolylthiourea, the crude product was dissolved in 300 ml of chloroform. The yield of rhodanine purified by heating with alcohol was 17.6 g (62.9%). For analysis the material was crystallized from 20 times the amount of isoamyl alcohol (carbon was used). The melting point after two crystallizations was 236°.

Found %: N 10.03, 9.97; S 34.32, 34.50. $C_{11}H_8ON_2S_3$.
Calculated %: N 10.00; S 34.28.

N-(Benzothiazolyl-2'-methyl)rhodanine (III). For the synthesis of rhodanine (III) 16.4 g of 2-aminomethylbenzothiazole [2] and 67.8 g of thiocarbonyl-bis-thioglycolic acid were used. The method of preparing rhodanine (III) was the same as in the cases of rhodanines (I) and (II). The yield of crude N-(benzothiazolyl-2'-methyl)rhodanine was 15.0 g. The crude rhodanine was dissolved in 150 ml of chloroform, the insoluble portion was filtered off, and a precipitate of rhodanine (III) separated from the filtrate upon cooling. After four crystallizations from 8 times the amount of chloroform, rhodanine (III) was obtained as pale yellow, fine crystals with m.p. 122°.

Found %: N 9.87, 10.08; S 34.58, 34.55. $C_{11}H_8ON_2S_3$.
Calculated %: N 10.00; S 34.28.

Condensation of Benzothiazolylrhodanines with Aldehydes

Equimolecular amounts of aldehyde of the aromatic or heterocyclic series and an amount of dry pyridine double the sum of the starting materials were boiled for 30 minutes. The mixture was left to cool, the yellow precipitate was filtered off and washed with dry ether. The yield of crude condensation product varied between 58 and 76%. The crude product was crystallized from toluene, xylene, or isoamyl alcohol (carbon was used).

3-(2'-Methylbenzothiazolyl-[6'])-5-benzylidenerhodanine (IV). The compound was prepared from 5.04 g (0.04 g (0.018 mole) of rhodanine (I) and 1.87 g (0.018 mole) of benzaldehyde in 15 ml of pyridine. The yield of crude condensation product was 4.4 g (73.3%). For analysis the material was crystallized twice from xylene. Pale yellow, fine crystals were obtained with m.p. 218°.

Found %: N 7.22, 7.53. $C_{18}H_{12}N_2S_3$.
Calculated %: N 7.60.

3-(2'-Methylbenzothiazolyl-[6'])-5-furfurylidenerhodanine (V). The compound was prepared from 1.12 g of rhodanine (I) and 0.39 g of furfural. The yield of crude condensation product was 1.0 g (69.9%). For analysis the product was crystallized twice from 80 times the amount of isoamyl alcohol. The fine, yellow crystals melted at 255°.

Found %: N 7.96, 7.88. $C_{16}H_{10}O_2N_2S_3$.
Calculated %: N 7.82.

3-(2'-Methylbenzothiazolyl-[6'])-5-phenylidenerhodanine (VI). The compound was prepared from 4.48 g of rhodanine (I) and 1.7 g of α-thiophenaldehyde. The yield of crude condensation product was 3.9 g (58.7%). For analysis the material was crystallized twice from 80 times the amount of xylene. Yellow, fine crystals with m.p. 259°.

Found %: N 7.64, 7.65; S 34.45, 34.57. $C_{16}H_{10}ON_2S_4$.
Calculated %: N 7.47; S 34.22.

3-(2'-Methylbenzothiazolyl-[5'])benzylidenerhodanine (VII). This compound was prepared from 1.12 g of rhodanine (II) and 0.42 g of benzaldehyde. The yield of crude condensation product was 0.94 g (68.0%). For analysis the material was crystallized twice from 25 times the amount of isoamyl alcohol. Fine yellow crystals with m.p. 219°.

Found %: N 7.75, 7.95, $C_{18}H_{12}ON_2S_3$.
Calculated %: N 7.60.

3-(2'-Methylbenzothiazolyl-[5'])-furfurylidenerhodanine (VIII). The compound was prepared from 1.12 g of rhodanine (II) and 0.39 g of furfural. The yield of crude condensation product was 0.84 g (58.7%). For analysis the material was crystallized twice from 120 times the amount of isoamyl alcohol. Fine, orange-yellow, lustrous crystals with m.p. 262°.

Found %: N 7.77, 7.58. $C_{16}H_{10}O_2N_2S_3$.
Calculated %: N 7.82.

3-(2'-Methylbenzothiazolyl-[5'])-5-phenylidenerhodanine (IX). The compound was prepared from 1.12 g of rhodanine (II) and 0.45 g of α-thiophenaldehyde. The yield of crude condensation product was 0.95 g (63.6%). For analysis the material was crystallized twice from 100 times the amount of isoamyl alcohol. Fine yellow crystals with m.p. 236°.

Found %: 7.57, 7.79: S 34.36. $C_{16}H_{10}ON_2S_4$.
Calculated %: N 7.47; S 34.22.

3-(Benzothiazolyl-[2'] -methyl)-5-benzylidenerhodanine (X). The compound was prepared from 1.12 g of rhodanine (III) and 0.42 g of benzaldehyde. The yield of crude condensation product was 1.12 g (76.1%). For analysis the material was crystallized twice from 100 times the amount of isoamyl alcohol. Light-yellow, fine crystals with m.p. 219°.

Found %. N 7.61, 7.72. $C_{18}H_{12}ON_2S_3$.
Calculated%: N 7.60.

3-(Benzothiazolyl-[2']-methyl)-5-furfurylidenerhodanine (XI). The compound was prepared from 1.12 g of rhodanine (III) and 0.39 g of furfural. The yield of crude condensation product was 1.24 g (86.3%). For analysis the material was crystallized from 50 times the amount of isoamyl alcohol. Orange-yellow, fine crystals with m.p. 229°.

Found %: N 7.70, 7.92. $C_{16}H_{10}O_2N_2S_3$.
Calculated %: N 7.82.

3-(Benzothiazolyl-[2']-methyl) -5-phenylidenerhodanine (XII). The compound was prepared from 1.12 g of rhodanine (III) and 0.45 g of α-thiophenaldehyde. The yield of crude condensation product was 1.12 g (74.3%). For analysis the material was crystallized twice from 100 times the amount of toluene. Fine, yellow crystals with m.p. 252°.

Found %: N 7.64, 7.62. $C_{16}H_{10}ON_2S_4$.
Calculated %: N 7.47.

Condensation of Benzothiazolylrhodanines with the Iodoethylate of 2-ω-Acetanilinovinyl) Benzothiazole and its Methoxy Derivatives (Synthesis of Dyes – Dimethinemerocyanines)

The iodoethylate of 2-(ω-acetanilinovinyl)benzothiazole (or its methoxy derivative) and benzothiazolylrhodanine, taken in a molecular ratio of 1:1.5, and dry pyridine in an amount four times the sum of the starting materials were boiled for 1 hour and left to stand. After 2-3 hours a red, crystalline precipitate of merocyanine began to separate. After 15-20 hours the precipitate was filtered off and washed with alcohol and dry ether. The yield of merocyanine was 85-98%. To purify the merocyanine it was crystallized from xylene and glacial acetic acid and washed with dry ether.

3-(2'-Methylbenzothiazolyl-[6'])-5-(3''-ethylbenzothiazolinylidene-2''-ethylidene)rhodanine (XIII). The compound was prepared from 6.3 g (0.014 mole) of the iodoethylate of 2-(ω- acetanilinovinyl)benzothiazole and 5.88 g (0.021 mole of rhodanine (I) in 48 ml of pyridine. The yield of merocyanine was 5.9 g (98%). For analysis the material was crystallized from 60 times the amount of xylene. Lustrous, violet-red crystals with m.p. 295°. A solution of the compound in ethyl alcohol had an absorption maximum at 528 mμ.

Found %: N 8.81, 8.83. $C_{22}H_{17}ON_3S_4$.
Calculated %: N 8.99.

3-(2'-Methylbenzothiazolyl-[6'])-5-(3''-ethyl-5''-methoxybenzothiazolinylidene-2''-ethylidene)rhodanine (XIV). The compound was prepared from 4.19 g of the iodoethylate of 5-methoxy-2-(ω-acetanilinovinyl)benzothiazole and 3.36 g of rhodanine (I). The yield of merocyanine was 3.8 g (96.2%). For analysis the compound was crystallized from 80 times the amount of glacial acetic acid and washed with hot water. Violet-red, lustrous crystals with m.p. 263°. A solution of the material in ethyl alcohol had an absorption maximum at 535 mμ.

Found %: N 8.28, 8.38; S 25.46. $C_{23}H_{19}O_2N_3S_4$.
Calculated %: N 8.45; S 25.75.

3-(2'-Methylbenzothiazolyl-[5'])-5-(3''-ethylbenzothiazolinylidene-2''-ethylidene)rhodanine (XV). The compound was prepared from 4.5 g of the iodoethylate of 2-(ω-acetanilinovinyl) benzothiazole and 4.2 g of rhodanine (II). The yield of merocyanine was 4.0 g (85.6%). For analysis the compound was crystallized from 60 times the amount of xylene. Violet-red, lustrous crystals with m.p. 284°. A solution of the material in ethyl alcohol had an absorption maximum at 528 mμ.

Found %: N 8.91, 8.77. $C_{22}H_{17}ON_3S_4$.
Calculated %: N 8.99.

3-(2'-Methylbenzothiazolyl- [5'])-5-(3''-ethyl-5''-methoxybenzothiazolinylidene-2''-ethylidene) rhodanine (XVI). The compound was prepared from 0.53 g of the iodoethylate of 5-methoxy-2-(ω-acetanilinovinyl)benzothiazole and 0.42 g of rhodanine (II). The yield of merocyanine was 0.46 g (92.5%). For analysis the compound was crystallized from 100 times the amount of xylene. Red crystals with a green luster, with m.p. 283°. A solution of the material in ethyl alcohol had an absorption maximum at 535 mμ.

Found %: N 8.23, 8.09. $C_{23}H_{19}O_2N_3S_4$.

Calculated %: N 8.45.

3-(Benzothiazolyl-[2']-methyl)-5-(3''-ethylbenzothiazolinylidene-2''-ethylidene) rhodanine (XVII). The compound was prepared from 0.45 g of the iodoethylate of 2-(ω-acetanilinovinyl) benzothiazole and 0.42 g of rhodanine (III). The yield of merocyanine was 0.42 g (85.6%). For analysis the compound was crystallized from 50 times the amount of xylene. Violet-red, lustrous crystals with m.p. 266°. A solution of the material in ethyl alcohol had an absorption maximum at 528 mμ.

Found % : N 9.03, 8.93. $C_{22}H_{17}ON_3S_4$.
Calculated %: N 8.99.

3-(Benzothiazolyl-[2']-methyl)-5-(3''-ethyl-5''-methoxybenzothiazolinylidene-2''-ethylidene)rhodanine (XVIII). The compound was prepared from 0.53 g of the iodoethylate of 5-methoxy-2-(ω-acetanilinovinyl) benzothiazole and 0.42 g of rhodanine (III). The yield of merocyanine was 0.45 g (90.5%). For analysis the compound was crystallized from a large excess of xylene. Brown-red crystals with a green luster, with m.p. 297°. A solution of the material in ethyl alcohol had an absorption maximum at 535 mμ.

Found % : N 8.21, 8.15. $C_{23}H_{19}O_2N_3S_4$.
Calculated %: N 8.45.

SUMMARY

1. Three new N-substituted rhodanines (2-oxothiazolidene-4-thiones) have been synthesized by the condensation of amino derivatives of 2-methylbenzothiazole with thiocarbonyl-bis-thioglycolic acid. Their properties have been studied and characteristic derivatives – products of condensation with aromatic and heterocyclic aldehydes – have been prepared.

2. From the new benzothiazolylrhodanines and the iodoethylates of 2-(ω-acetanilinovinyl)benzothiazole and 2-(ω-acetanilinovinyl)-5-methoxy-benzothiazole there have been obtained dyes – dimethinemerocyanines – for which the positions of their absorption maxima have been determined.

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INVESTIGATION OF CARBONYL DERIVATIVES OF BENZENE BY OTHER SPECTROGRAPHIC AND OTHER PHYSICOCHEMICAL METHODS

I. INVESTIGATION OF 1,3-DIACETYLBENZENE*

F. F. Cheshko and B. G. Distanov

Spectrography is used more and more often with great success for establishing the structure of medicinal materials and antibiotics [1, 2]. This method also makes it possible to show more completely the relation between the structure and the physiological activity of various compounds [2]. Changes in the activity of antibiotics when hydroxyl and methoxyl groups are introduced in different positions, changes produced by the action of solvents [3], and other mechanisms that are observed make necessary a thorough study of the structures of the molecules and of the changes that occur in their electron systems. The investigations by N. A. Valyashko and his students of the acetyl and hydroxyacetyl derivatives of benzene have made it possible to establish a number of rules for the interaction of functional groups with the benzene ring.

Our investigations of the derivatives of benzene that contain two acetyl and one or two hydroxyl or methoxyl functional groups are a continuation of the investigations of N. A. Valyashko and his school. Functional groups in such a combination are characteristic of many medicinal materials, antibiotics, enzymes, hormones, and the like. We have carried out polarographic, spectrographic, and conductometric studies of dilute solutions of compounds containing carbonyl and hydroxyl (or methoxyl) groups. These investigations by many methods permit us to present a mechanism for the action of the medium (solvent) on the molecule that determines the manifestation of its properties [4-7].

EXPERIMENTAL

Spectrographic investigation of 1,3-diacetylbenzene

The spectrography was carried out in an ISP-22 spectrograph. For spectrographic measurements, materials purified to a constant spectrum before investigation were used. 1,3-Diacetylbenzene was synthesized by the oxidation of 3-ethylacetophenone [8-10].

1,3-Diacetylbenzene had not been investigated previously. We studied 1,3-diacetylbenzene in isooctane, ethanol, water, sodium ethylate solutions, and sulfuric acid solutions at concentrations of 10^{-2}, 10^{-3}, 10^{-4}, and 10^{-5}M. The absorption curve for 1,3-diacetylbenzene in isooctane (Fig. 1, curve 1) shows an absorption band with a maximum at λ 3250 A and ϵ 140. An absorption band in the middle ultraviolet region is made up of two narrow bands with maxima at λ 2960 A, ϵ 750, and λ 2815 A, ϵ 750. In the short-wave region an absorption band is noted approximately at λ 2350 A and ϵ 17,380, which overlaps a definitely indicated, incomplete band at λ 2185 A and ϵ 42,000. A comparison of the spectra of 1,3-diacetylbenzene in isooctane and of acetophenone in hexane [11, 12] shows their considerable similarity.

The absorption spectrum of 1,3-diacetylbenzene in ethanol (Fig. 1, curve 2) differs from that in isooctane. The low-intensity ban loses its distinctness. The band in the middle ultraviolet region is not divided and is increased in intensity 1.7 times. The absorption spectrum of 1,3-diacetylbenzene in water was studied, because of the low solubility, only at concentrations of 10^{-3}, 10^{-4}, and 10^{-5} M. It corresponds with the spectrum of diacetylbenzene in ethanol (Fig. 1, curve 3). In the absorption spectrum of 1,3-diacetylbenzene, regularities are observed in going from isooctane to water that were previously noted by Valyashko and Rozum [11] in the case of acetophenone in these same solvents, but less clearly expressed. Addition of 2 moles of ethanol to 1 mole of 1,3-diacetylbenzene (Fig. 1, curve 6) did not affect the absorption spectrum. Addition of sodium ethylate in a smaller amount than the 1:1 ratio did not affect the absorption spectrum of 1,3-diacetylbenzene in ethanol. With a ratio of 1 mole of sodium ethylate to 1 mole of 1,3-diacetylbenzene the absorption spectrum in ethanol solution was changed (Fig. 1, curve 4), the band in the middle ultraviolet region was diminished in intensity 1.6 times, preserving the relative position of the wavelengths. A further increase in the concentration of the sodium ethylate did not show any effect on the absorption spectrum (Fig. 1, curve 5).

1,3-Diacetylbenzene was studied in ethanolic solutions of sulfuric acid containing 10, 100, 1000, 14,000, and 17,000 moles of the latter to 1 mole of diacetylbenzene. With 10 and 100 moles of acid per mole of material the absorption spectrum of 1,3-diacetylbenzene did not differ from its spectra in ethanol (Fig. 2, curves 2, 3). With subsequent increase of the amount of sulfuric acid to 10,000 moles, the long-wave portion of the absorption spectrum (Fig. 2, curve 5) was displaced toward the longer wavelengths. by 150-180 A. A discontinuity in the curve upon dilution indicates alcoholysis of the product formed by the reaction of 1,3-diacetylbenzene with sulfuric acid. The spectrum returns to that of diacetylbenzene in the presence of 1000 moles of sulfuric acid. An increase in the concentration to 14 000 moles (Fig. 2, curve 6) leads to further displacement of the absorption toward the long-wave region by 425 A relative to the absorption in ethanol. Upon dilution, the absorption returns to that of 1,3-diacetylbenzene in ethanol in the presence of 1000 moles of sulfuric acid (Fig. 2, curve 4). 17,000 Moles of sulfuric acid did not cause any further change (Fig. 2, curve 7). The absorption spectrum of 1,3-diacetylbenzene after neutralization of 17 000 moles of sulfuric acid with ethanol solution of sodium ethylate (Fig. 2, curve 8) did not differ from its absorption spectrum in ethanol. This indicates that there was no sulfonation under the conditions of our investigation.

The curve for the absorption spectrum of 1,3-diacetylbenzene in aqueous sulfuric acid (Fig. 2, curve 8) repeats the curve for diacetylbenzene in ethanolic sulfuric acid in the amount of 17 000 moles of the latter to 1 mole of the compound under investigation.

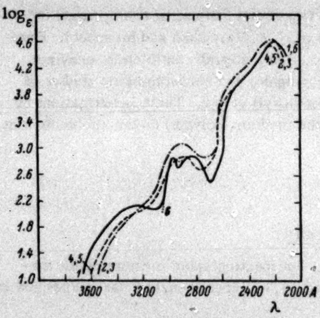


Fig. 1. Absorption spectra of 1,3-diacetylbenzene.
1) in isooctane (10^{-2}–10^{-5} M), 2) in ethanol, 3) in water, 4) in ethanol + 1 mole C_2H_5ONa, 5) in ethanol + 10 moles C_2H_5ONa, 6) in isooctane + 2 moles of ethanol.

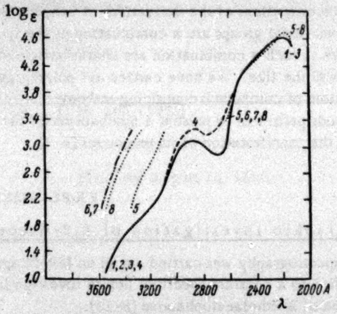


Fig. 2. Absorption spectra of 1,3-diacetylbenzene.
1) in ethanol (10^{-2}–10^{-5} M), 2) same + 10 moles H_2SO_4 (10^{-3}–10^{-5}), 3) same + 100 H_2SO_4, 4) same + 1000 moles H_2SO_4, 5) same + 10 000 moles H_2SO_4, 6) same + 14 000 moles H_2SO_4, 7) same + 17 000 moles H_2SO_4, 8) same + 17 000 moles H_2SO_4 (after neutralization with ethanolic solution of sodium ethylate).

Discussion of results of spectrographic investigation

Derivatives of benzene, and in particular carbonyl derivatives, have been subjected to detailed spectrographic investigation. Absorption bands in their spectra are explained by several factors: the benzene ring [13-17], the carbonyl group [18-19], their interaction [18-21], and association phenomena [22-24]. The absorption spectra of acetophenone [11] and 1,3-diacetylbenzene in the same or similar solvents, as has been shown, are very much alike in character. The general character of the spectrum is preserved, only the intensity of the absorption bands is changed and some shift in absorption to the long-wave region is observed. Data on the position of the absorption bands of 1,3-diacetylbenzene is isooctane and of acetophenone in hexane are given in Table 1.

From the data in Table 1 it is seen that the principal changes in the absorption spectrum of acetophenone observed upon introducing a second acetyl group have to do with the absorption bands present in the long-wave (λ 3250 A) and the far ultraviolet regions (λ 2370 A), while the intensity of the band in the middle ultraviolet region is diminished only a trifle. The increase in intensity of the absorption in the long-wave region (λ 3250 A), which is dependent upon the electron system of the carbonyl group [25], can be explained by the creation of two centers of absorption as a result of the conjugation of both acetyl groups with the benzene ring.

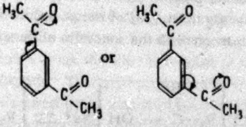


TABLE 1

Compounds	Maxima of absorption bands									
	Long-wave region		Middle ultraviolet region				Short-wave region			
	λ	ε	λ	ε	λ	ε	λ	ε	λ	ε
Aoetophenone.	3250	50	2880	900	2770	1000	2370	13000	—	—
1,3-Diacetylbenzene.	3250	140	2960	750	2815	750	2550, 2350	6400, 20000	2185	42000

The presence of an absorption band for a carbonyl group of aliphatic ketones in the region λ 2800 A [26] does not contradict the assumption that the absorption in the region λ 3250 A in the case of 1,3-diacetylbenzene is also dependent on the presence of a carbonyl group, since in this instance we are considering not an isolated electron system of the carbonyl group but one conjugated with the π-electron system of the benzene ring. The decrease in energy of the electron system as a result of conjugation also leads to the shift observed to the region of longer waves by 450 A.

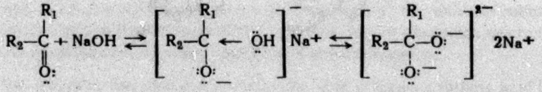
The general shift observed in the absorption of 1,3-diacetylbenzene relative to the absorption of acetophenone toward the longer waves by 50-100 A is a result of the decrease in total energy of the π-electron system of diacetylbenzene with the introduction of the second acetyl group.

Purvis [27] found for aliphatic ketones that with a decrease in the number of absorption centers there is a shift to the more highly refracting region.

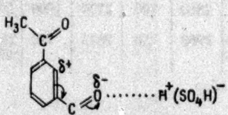
Upon going from a solvent with a lower dielectric permeability to a solvent with a greater dielectric permeability ($2 \leq D \leq 80.4$), regular shifts of the absorption to the long-wave region and an increase in intensity of the absorption band in the middle ultraviolet region (Fig. 1, curves 1-5) are observed. Valyashko and Rozum [11] also observed similar shifts on going from one solvent to another. These shifts may occur as a result of strengthening the interaction of the noncovalent pair of electrons of the carbonyl group with the molecular dipole of the solvent [26] or as a result of the formation of a hydrogen bond [2]. An increase in the dielectric permeability leads to a decrease in the vibration frequency, and consequently to a decrease in energy of the electron system $E = h\nu$ [29]. The number of absorbing molecules is decreased and the intensity of the absorption band is increased (Fig. 1, curve 1, 2). The lowering noted by Bloch and Rumpf [30] in the intensity of the carbonyl absorption band in aqueous solutions of aliphatic ketones as a result of hydration does not occur in the case of 1,3-diacetylbenzene. Acetophenone also does not give such an effect [11].

The absorption spectra of 1,3-diacetylbenzene in the presence of 1 and 10 moles of sodium ethylate (Fig. 1, curves 4, 5) are changed only a trifle in the direction of lowering of the intensity of the absorption bands. According to the data of Valyashko and Rozum [11], a further increase in the amount of sodium ethylate up to 2000 moles to 1 mole of the compound under investigation does not substantially change the absorption spectra. However, from the absence of significant change in the absorption spectra of 1,3-diacetylbenzene in ethanolic solutions of sodium ethylate it still does not follow that there is no interaction between the carbonyl group and sodium ethylate. The interaction may be hidden by the leveling effect of the solvent [31].

The hydration of aliphatic ketones [30] and the addition of sodium hydroxide to the carbonyl group, according to Eistert [32], makes it possible to propose the reaction of the carbonyl group of 1,3-diacetylbenzene with sodium ethylate. Valyashko's investigations [33] of the acetal of benzaldehyde in ethanol showed only slight changes in the spectrum in comparison with the spectrum of benzaldehyde.



Numerous investigations of acetyl derivatives of benzene in concentrated solutions of sulfuric acid have shown the existence of products of their reaction [34-40]. Slight successive changes in intensity and position of the bands of the absorption spectra of ethanol solutions of 1,3-diacetylbenzene in the presence of 10, 100, and 1000 moles of sulfuric acid (Fig. 2, curves 2-4) can be explained as a consequence of the influence of the dielectric permeability of the medium (solvent) on the absorption of 1,3-diacetylbenzene. With 1000 moles of sulfuric acid, at a concentration in ethanol of 53% (Fig. 2, curve 5), apparently an oxonium sulfate of 1,3-diacetylbenzene is formed, for example (A).



(A)

With 14 000 moles of sulfuric acid, which corresponds to a 74% ethanolic solution of sulfuric acid, the formation of the oxonium sulfate of 1,3-diacetylbenzene is completed. This is confirmed by the identity of the absorption spectra of 1,3-diacetylbenzene in the presence of 14 000 and 17 000 moles of sulfuric acid (Fig. 2, curves 6,7).

Dilution of the salt-forming sulfuric acid solutions of 1,3-diacetylbenzene brings about the alcoholysis of the oxonium sulfate of 1,3-diacetylbenzene. As a result of the alcoholysis, absorption is again observed in the region characterizing the electron structure of the 1,3-diacetylbenzene molecule in ethanol solution of sulfuric acid below 50% concentration (less than 1000 moles). Alcoholysis eliminates the effect of the oxonium sulfate on the absorption spectrum, and only the effect of the dielectric permeability of the sulfuric acid medium remains (Fig. 2, curve 8).

Replacement of the ethanol by water, a solvent with a higher dielectric permeability (80.4 in comparison with 27.8 at 20° [41]), weakens the electrostatic force of the reaction in conformance with Coulomb's law $F = \text{const.}\frac{1}{D}$. The oxonium salt dissociates to some extent into sulfuric acid and 1,3-diacetylbenzene. This corresponds with the movement of the absorption in the direction of the spectral region characterizing the energy of the electron system of 1,3-diacetylbenzene.

The formation of the oxonium sulfate of 1,3-diacetylbenzene creates a molecular system in which the number of degrees of freedom of the π-electrons is significantly increased, and the energy of the electron system as a result of this is decreased. According to Einstein's formula, $E = \text{const.}\,\frac{1}{\lambda}$, a decrease in energy of the electron system is accompanied by a shift of the absorption to the long-wave region (Fig. 2, curves 5-7).

The reaction of sulfuric acid with the carbonyl group of 1,3-diacetylbenzene, apparently, does not amount to dissociation of the oxonium sulfate, since the energy of the proton bond with the hydroxyl oxygen of sulfuric acid is greater than the energy of the proton bond with the carbonyl oxygen of the ketone [42].

Polarographic and conductometric investigation of 1,3-diacetylbenzene

The investigation was carried out in a micropolarograph of the Gierovsky system type M-102 with a constant total concentration of the binary system consisting of the compound under study and sodium hydroxide, the sensitivity of the galvanometer was from 1/50 to 1/300 maximum (3.8×10^{-9}); the difference in potential at the electrodes was from 0 to 4 v; the dropping rate of the mercury at the cathode was 2 drops per second. Water and ethanol were used as solvents. The effect of the solvents on the reduction potential was not studied [43], since the object of the investigation was not the absolute value of the potential, but the relative changes in it under the influence of sodium hydroxide. The half-wave potentials were determined in the polarograms by the graphic method, and from them were constructed composition-reduction potential curves. In the ethanol solutions indications of oxidation-reduction processes were not detected. Therefore the investigation was carried out in aqueous solutions. The waves with a potential of about 0.9 v we related to oxygen and did not study them. The polarographic investigation of 1,3-diacetylbenzene was carried out at a molar ratio of this compound to sodium hydroxide of 1 : 1, 1 : 2, 1 : 4, and 1 : 9 with a total concentration of the system of 10^{-3}M (Fig. 3).

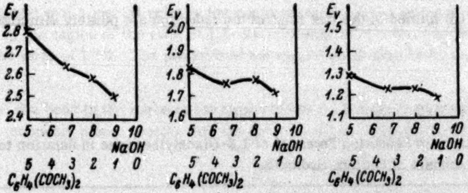


Fig. 3. Reduction potentials of the binary system $C_6H_4(COCH_3)_2$– NaOH.

The polarograpm contains three waves, the potentials of which are distinct from the reduction potential of sodium hydroxide. The value of the reduction potentials changes with a change in the amount of sodium hydroxide. The composition-reduction potential curves show the presence of a special point at a ratio of the compound under investigation to sodium hydroxide of 1 : 4 (Fig. 3). Changes beyond this special point are hyperbolic (Table 2).

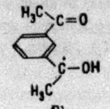
The conductometric investigation of 1,3-diacetylbenzene was carried out by the compensation method according to the procedure of Semenko; a type VG vibration galvanometer was used as the null-instrument.

Determination of the specific electrical conductivity was carried out in aqueous solution at molar ratios of the compound investigated to sodium hydroxide of 4 : 1, 2 : 1, 1 : 1, 1 : 2, 1 : 4, and 1 : 9 with a total concentration equal to 10^{-3} M. As the amount of sodium hydroxide was increased, the electrical conductivity of the system 1,3-diacetylbenzene-sodium hydroxide increased hyperbolically up to a value of $88.9 \cdot 10^{-6}$ ohm^{-1} cm^{-1}. In the region of the molar ratio of 1,3-diacetylbenzene to sodium hydroxide of 1 : 4, there was a special point. The hyperbolic relationship was altered: the focal distance increased and the electrical conductivity rose to 140.8 $ohm^{-1} cm^{-1}$.

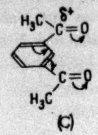
When a second acetyl group was introduced into the benzene ring, a change was observed in the magnitude of the reduction potential compared to acetophenone. Some of the difference in the reduction potentials given by different authors [44-46], apparently, is a result of a difference in the experimental conditions. Our polarographic investigations of the binary system 1,3-diacetylbenzene-sodium hydroxide show a decrease in the reduction potential of 1,3-diacetylbenzene compared with acetophenone. The polarogram of 1,3-diacetylbenzene contains three waves, while the polarogram of acetophenone has only one.

Because of the similarity of the first wave in the polarogram of 1,3-diacetylbenzene to the wave in the polarogram of acetophenone, it may be considered the result of the reduction of the first acetyl group. The second wave, which is absent in the polarogram of acetophenone, is explained by us as due to the reduction of the second acetyl group. The first wave corresponds to a reduction potential less by 0.22 v than that of acetophenone (Fig. 3); the second wave, which is absent in acetophenone, corresponds to a reduction potential higher than the first by 0.5 v.

The decrease in the reduction potential of the first acetyl group, which leads to the formation of the free radical (B), is a result of the effect of the second acetyl group, which weakens the conjugation of the π-electron system of the benzene ring with the reduced acetyl group. The second acetyl group, drawing out the electrons of the benzene ring, hampers the compensation of the positive charge of the carbonyl carbon atom of the reduced acetyl group. Its electron density is decreased, or, in other words, its positive charge (C) is increased.



(B)



(C)

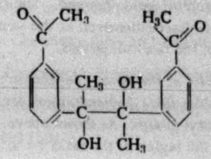
As a result of this, the reduced acetyl group is easily drawn to the cathode and takes on electrons from it.

The free radicals (B) formed in the first stage of the reduction are possibly dimerized with the formation of glycols (D) [47-49].

TABLE 2

Changes in Reduction Potential of 1,3-Diacetylbenzene in Relation to the Amount of Sodium Hydroxide

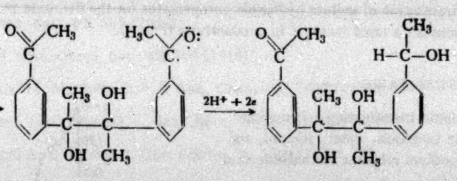
Concentration of components of the system (moles/ $1 \cdot 10^{-3}$)		Reduction potential in region		
1,3-diacetylbenzene	sodium hydroxide	1.15–1.3 v	1.7–1.85 v	2.5–2.8 v
0.5	0.5	1.39	1.82	2.78
0.33	0.67	1.24	1.74	2.64
0.2	0.8	1.24	1.75	2.58
0.1	0.9	1.18	1.70	2.49



(C)

The presence of the second wave in the polarogram in the region of the potential 1.70-1.72 v possibly is a result of the reduction of the second acetyl group of the glycol.

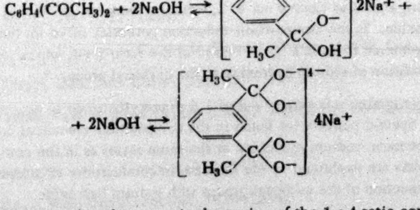
(D) →



The greater value of the reduction potential of the second acetyl group by almost 0.5 v is a result of the elimination of the effect of one of the acetyl groups after its reduction, and also of the fact that twice as great a number of protons and electrons in the molecule participate in the reduction.

In the literature there are widespread, contradictory opinions about the relation between the changes in reduction potential of carbonyl compounds and the shift of the absorption bands in their spectra [43-50]. The absorption band of 1,3-diacetylbenzene is almost unchanged in comparison to acetophenone, while the reduction potential is diminished. The polarographic investigation of the binary system 1,3-diacetylbenzene-sodium hydroxide shows the presence of a special point in the composition-reduction potential curves (Fig. 3). There is a bend in the curve in the region of the ratio of 1,3-diacetylbenzene to sodium hydroxide of 1 : 2, and a more distinct one at the ratio of 1 : 4. The presence of the special point may be caused by the appearance of reaction products.

The beginning of the bend in the curve in the region of the 1 : 2 ratio corresponds to this process. It is further possible that a secondary process occurs with the reaction of two more molecules of sodium hydroxide.



The completion of the bend in the curve in the region of the 1 : 4 ratio corresponds to this process.

The increase in the reduction potential in the region of the bend in the curve agrees with the change in the electron makeup of the carbonyl group. Partial compensation of the lowered electron density of the carbon atom at the expense of the electrons of the hydroxyl ion leads to a hampering of the reduction process.

In alkali solutions the intermolecular reaction of the carbonyl groups through the benzene ring is changed by the intramolecular reactions of both carbonyl groups with the sodium hydroxide.

The conductometric investigation of the binary system 1,3-diacetylbenzene-sodium hydroxide shows a disturbance of the uniformity of the development of the composition-conductivity curves of the system in the same region where the changes in reduction potential were observed. The similarity of the changes in reduction potential and electrical conductivity of 1,3-diacetylbenzene at the same ratio with sodium hydroxide is evidence of the presence of reaction products of the two compounds.

Since the changes in electrical conductivity of the system depend on the ionization product of the reaction of 1,3-diacetylbenzene and sodium hydroxide, the 1,3-diacetylbenzene must take part in it as a result of the addition of sodium hydroxide to the two acetyl groups. As shown above, the formation of a reaction product corresponds with the change in conductivity in the region of the ratio 1 : 2. Further, a secondary process develops that leads to the addition of two more molecules of sodium hydroxide (see above), to which the change in conductivity in the region of the ratio 1 : 4 corresponds. The appearance in the solution of ions with many charges leads to a rapid increase in conductivity at the transition point. The increase in conductivity then becomes moderate because of the exclusion from the process of the bound, highly mobile hydroxyl ions. A further steady increase in concentration of sodium hydroxide compensates for the decrease in bound hydroxyl anions and again provides conditions for a rapid increase in conductivity (Fig. 4).

SUMMARY

1. A spectrographic investigation was made of 1,3-diacetylbenzene in isooctane, water, ethanol, and ethanolic solutions of sodium ethylate and sulfuric acid.

2. In the absorption spectra of 1,3-diacetylbenzene there are three groups of bands:—in the long-wave, middle ultraviolet, and short-wave regions; an explanation has been given for the genesis of these three groups of bands.

3. The general similarity of the absorption spectra of 1,3-diacetylbenzene to those of acetophenone has been established; some difference in the absorption spectra of 1,3-diacetylbenzene and acetophenone is explained by the separate conjugation of the two acetyl groups with the benzene ring.

4. It has been established that in solutions of sulfuric acid of concentrations higher than 50% an oxonium salt of 1,3-diacetylbenzene is formed.

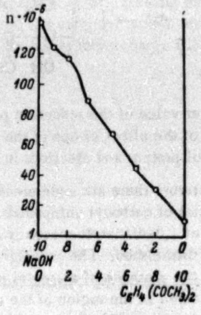


Fig. 4. Electrical conductivity of the binary system $C_6H_4(COCH_3)_2$–NaOH.

5. It has been shown that the absorption of 1,3-diacetylbenzene is directly dependent on the dielectric permeability of the solvent.

6. A polarographic investigation was carried out of 1,3-diacetylbenzene in ethanol and water solutions in the presence of sodium hydroxide. In the composition-reduction potential curve for the binary system 1,3-diacetylbenzene-sodium hydroxide there is a special point at the ratio 1 : 4, which is explained by the formation of a product of the addition of sodium hydroxide to the carbonyl group.

7. A conductometric investigation was carried out of 1,3-diacetylbenzene in aqueous solution in the presence of sodium hydroxide. Special points were found in the composition-electrical conductivity curves of the binary system 1,3-diacetylbenzene-sodium hydroxide at the same ratios as in the composition-reduction potential curve; the special points are explained by the increase in conductivity as a result of the formation of ions with many charges by the reaction of the carbonyl groups with sodium hydroxide.

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INVESTIGATION OF CARBONYL DERIVATIVES OF BENZENE BY SPECTROGRAPHIC AND OTHER PHYSICOCHEMICAL METHODS.

II. INVESTIGATION OF 1-HYDROXY-2,4-DIACETYLBENZENE.

F. F. Cheshko and B. G. Distanov

Spectrographic Investigation

1-Hydroxy-2,4-diacetylbenzene has been prepared by the Fries rearrangement of o- and p-acetoxyacetophenone [1-4]. It had not previously been studied. We have investigated 1-hydroxy-2,4-diacetylbenzene in isooctane, ethanol, water, and ethanolic solutions of sodium ethylate and sulfuric acid at concentrations of 10^{-2}, 10^{-3}, 10^{-4}, and 10^{-5} M.

The methyl ether of 1-hydroxy-2,4-diacetylbenzene, which has not been described in literature, was prepared by the methylation of 1-hydroxy-2,4-diacetylbenzene with a double excess of dimethyl sulfate in alkaline medium at 80-90°; an excess of sodium hydroxide was added with cooling; the ether, which is insoluble in alkalies, was separated. Yield 30-35%. The methyl ether of 1-hydroxy-2,4-diacetylbenzene is soluble in ethanol and diethyl ether, slightly soluble in petroleum ether. After 4 recrystallizations from ethanol, it formed white needles with m. p. 71°. It was purified before spectrographing by repeated recrystallization from optically pure ethanol until the spectrum was constant. The methyl ether of 1-hydroxy-2,4-diacetylbenzene was investigated in isooctane, ethanol, water, ethanolic solutions of sodium ethylate and sulfuric acid at concentrations of 10^{-2}, 10^{-3}, 10^{-4}, and 10^{-5} M.

The curve for the absorption spectrum of 1-hydroxy-2,4-diacetylbenzene in isooctane (Fig. 1, curve 1) at the concentrations mentioned shows absorption bands at λ 3250 A and ϵ 3600, λ 2660 A and ϵ 15 500, and λ 2070 A and ϵ 25 000. The absorption curve fo 1-hydroxy-2,4-diacetylbenzene in ethanol (Fig. 1, curve 2) in the main duplicates the curve in isooctane with respect to character and form. The absorption spectrum curve for 1-hydroxy-2,4-diacetylbenzene in water (Fig. 1, curve 3) differs from that in isooctane in that there is a shift of the absorption bands at λ 3250 A and λ 2660 A by 100 A each toward the short-wave region. The band in the middle ultraviolet region is weakened 1.5 times, and the band in the far ultraviolet region is strengthened 1.5 times.

1-Hydroxy-2,4-diacetylbenzene in ethanol solution of sodium ethylate was studied at ratios of 1 : 0.1, 1 : 0.5, 1 : 0.75, 1 : 1, 1 : 2, 1 : 10, and 1 : 100. The principal changes in the position of the absorption bands of 1-hydroxy-2,4-diacetylbenzene occur in the interval from 0.1 to 10 moles of sodium ethylate to 1 mole of the compound under investigation (Fig. 2, curves 2-7).

The curve for the absorption spectrum of 1-hydroxy-2,4-diacetylbenzene in ethanol solution of sulfuric acid at ratios of 0.1, 0.5, 1.2, and 100 moles of acid to 1 mole of 1-hydroxy-2,4-diacetylbenzene (Fig. 3, curves 2-8) fully duplicates the absorption curve of 1-hydroxy-2,4-diacetylbenzene in ethanol. An increase in the amount of sulfuric acid to 1000 moles leads to a sharp change in the absorption spectrum of 1-hydroxy-2,4-diacetylbenzene (Fig. 3, curve 9). At 10 000 and 17 000 moles of sulfuric acid, a shift amounting to 350 A relative to the spectrum of 1-hydroxy-2,4-diacetylbenzene in ethanol occurs. After dilution of the solution with ethanol, the absorption spectrum curve in both cases returns to the curve for the absorption in the presence of 100 moles of sulfuric acid (Fig. 3, curve 8). The absorption spectrum of 1-hydroxy-2,4-diacetylbenzene after neutralization of 17 000 moles of sulfuric acid with ethanol solution of sodium ethylate duplicates its spectrum in ethanol (Fig. 3, curve 1).

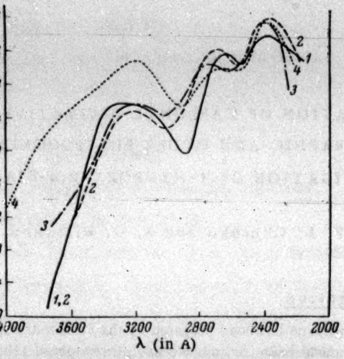


Fig. 1. Absorption spectra of 1-hydroxy-2,4-diacetylbenzene. 1) in isooctane (10^{-2} - 10^{-5} M), 2) in ethanol, 3) in water, 4) in ethanol + 1 mole of C_2H_5ONa

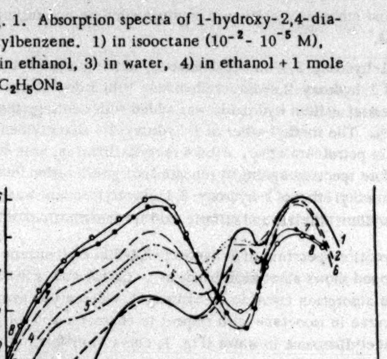


Fig. 2. Absorption spectra of 1-hydroxy-2,4-diacetylbenzene. 1) in ethanol (10^{-2} - 10^{-5} M), 2) + 0.1 mole C_2H_5ONa, 2) + 0.1 mole C_2H_5ONa, 3) + 0.5 mole C_2H_5ONa, 4) + 0.75 mole C_2H_5ONa, 5) + 1 mole C_2H_5ONa, 6) + 2 moles C_2H_5ONa, 7) + 10 moles C_2H_5ONa, 8) + 100 moles C_2H_5ONa.

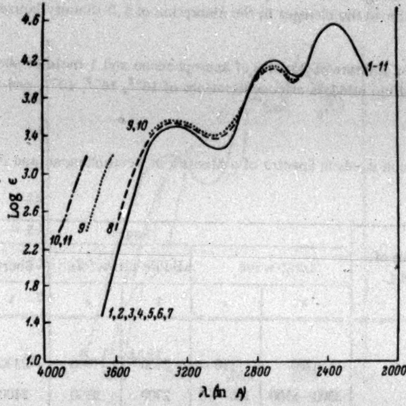


Fig. 3. Absorption spectra of 1-hydroxy-2,4-diacetylbenzene. 1) in ethanol (10^{-2} - 10^{-5} M), 2) + 0.1 mole H_2SO_4, 3) + 0.5 mole H_2SO_4, 4) + 0.75 mole H_2SO_4, 5) + 1 mole H_2SO_4, 6) + 2 moles H_2SO_4, 7) + 10 moles H_2SO_4, 8) + 100 moles H_2SO_4, 9) + 1000 moles H_2SO_4, 10) + 10 000 moles H_2SO_4, 11) + 17 000 moles H_2SO_4.

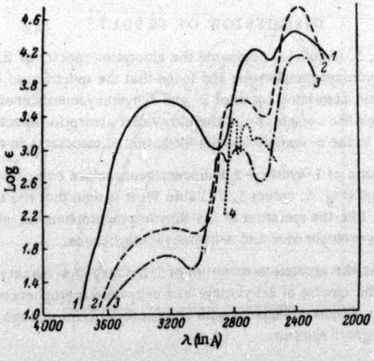


Fig. 4, Absorption spectra. 1) 1-hydroxy-2,4-diacetyl benzene in isooctane (10^{-2}–10^{-5} M), 2) acetophenone (2 moles) + phenol (1 mole) in isooctane (10^{-2} - 10^{-5} M), 3) acetophenone in hexane, 4) phenol in pentane.

The character of the change in the absorption spectra of 1-hydroxy-2,4-diacetylbenzene in ethanol solutions of sulfuric acid is similar to the changes in the absorption of 1,3-diacetylbenzene under the same conditions [17].

We have investigated a mixture of 2 moles of acetophenone and 1 mole of phenol in isooctane, ethanol, and ethanolic solution of sodium ethylate at concentrations of 10^{-2}, 10^{-3}, 10^{-4}, and 10^{-5} M (Table 1).

TABLE 1

Position of Absorption Bands in Spectra of a Mixture of Acetophenone and Phenol in Different Solvents (Fig. 4)

Mixture of 2 moles of acetophenone and 1 mole of phenol	Region					
	Long-wave		Middle ultraviolet		Short-wave	
	λ	ε	λ	ε	λ	ε
In isooctane	3200	110	2700	3800	2300	51300
In ethanol	3300—3100	150—90	2700	3390	2400	42700
In ethanolic solution of sodium ethylate	3400—3150	200—64	2830	6760	2430	43650

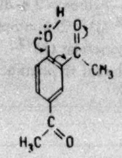
In the absorption spectrum of 1-methyl-2,4-diacetylbenzene in isooctane (Fig. 5, curve 2) a band is noted at λ 3450-3250 A and also a well-defined band at λ 2990 A, ε 3880 and two high-intensity bands at λ 2620 A, ε 41 700 and λ 2330 A, ε 77 600. The absorption of 1-methoxy-2,4-diacetylbenzene in ethanol (Fig. 5, curve 3) differs considerably from the absorption in isooctane.

DISCUSSION OF RESULTS

N. A. Valyashko and Yu. S. Rozum [5] compared the absorption spectra of 2,4-dihydroxyacetophenone with the spectra of 2- and 4-hydroxyacetophenone and found that the spectrum of 2,4-dihydroxyacetophenone is composed of the characteristic absorption bands of 2- and 4-hydroxyacetophenone, with a few changes in intensity. Schulze [6] explained the complexity of the ultraviolet absorption spectra by the formation of an intramolecular hydrogen bond in the o-isomers and the formation of associates in the p-isomers.

When the absorption spectra of 1-hydroxy-2,4-diacetylbenzene are compared with the spectra of 2,4-dihydroxyacetophenone in ethanol (Fig. 6, curves 1,2) (Table 2), it is seen that the spectrum of 1-hydroxy-2,4-diacetylbenzene can be regarded, like the spectrum of 2,4-dihydroxyacetophenone, as being made up of the absorption spectra of 2-hydroxyacetophenone and 4-hydroxyacetophenone.

It may be assumed that in the absorption spectrum of 1-hydroxy-2,4-diacetylbenzene there are bands corresponding to the bands of the spectra of 2-hydroxy- and 4-hydroxyacetophenones. This permits the conclusion that the hydroxyl group, OH, is conjugated with both acetyl groups through the benzene ring, forming the appropriate 2- and 4-conjugated systems:



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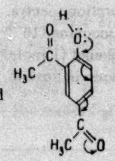


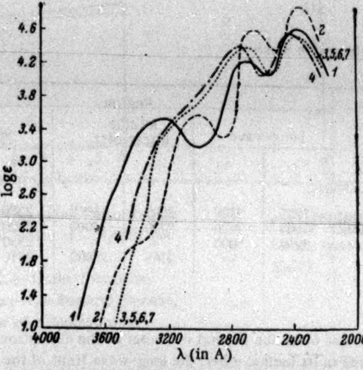


Fig. 5. Absorption spectra.
1) 1-hydroxy-2,4-diacetylbenzene in ethanol (10^{-2} - 10^{-5} M)
2) 1-methoxy-2,4-diacetylbenzene in isooctane (10^{-2} - 10^{-5} M),
3) same in ethanol, 4) same in water, 5) same in ethanol + 1 mole C_2H_5ONa, 6) same in ethanol + 10 moles C_2H_5ONa,
7) same in ethanol + 100 moles C_2H_5ONa.

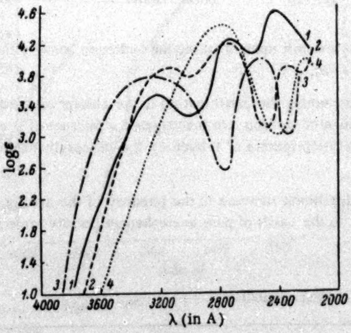


Fig. 6. Absorption spectra.
1) 1-hydroxy-2,4-diacetylbenzene in ethanol (10^{-2} - 10^{-5} M), 2) 2,4-dihydroxyacetophenone in ethanol,
3) 2-hydroxyacetophenone in ethanol, 4) 4-hydroxyacetophenone in ethanol

With the ortho-conjugated, a hydrogen bond also is formed, as is shown by the absorption spectrum of the methyl ether of 1-hydroxy-2,4-diacetylbenzene in ethanol.

TABLE 2

Position of Maxima of Absorption Bands

Compound	Region					
	Long-wave		Middle ultraviolet		Short-wave	
	λ	ε	λ	ε	λ	ε
1-Hydroxy-2,4-diacetylbenzene	3225	3100	2685	18060	2380	40000
2,4-Dihydroxyacetophenone	31600	7000	2700	15000	2320	8000
2-Hydroxyacetophenone.	3250	5000	—	—	2530	10000
4-Hydroxyacetophenone.	—	—	2765	25000	2210	10000

In Fig. 5 (curve 2) it is seen that while the general character of the absorption of 1-hydroxy-2,4-diacetylbenzene in ethanol is preserved in its methyl ether, the long-wave limit of the absorption is shifted in the short wave direction by 220 A, which corresponds to an energy change of 5.14 kcal/mole. The energy change is commensurate with the energy of the hydrogen bond [7-9].

The energy change was calculated on the basis of the graphic expression of the Lambert-Beer-Schwarzschild law by the formula

$$\Delta E = E_{\text{ether}} - E_{\text{phenol}} = \frac{Nhc}{\lambda_{\text{ether}}} - \frac{Nhc}{\lambda_{\text{phenol}}} = Nhc\left(\frac{1}{\lambda_{\text{ether}}} - \frac{1}{\lambda_{\text{phenol}}}\right) =$$

$$= \frac{6.02 \cdot 10^{23} \cdot 6.62 \cdot 10^{27} \cdot 3 \cdot 10^{10}}{4.18 \cdot 10^{7} \cdot 10^{3}}\left(\frac{1}{3540} - \frac{1}{3760}\right) = 5.14 \text{ cal/ mole}$$

Valyashko and Rozum found the shift upon breaking the hydrogen bond by the methylation of 2-hydroacetophenone to be equal to 280 A [5].

To verify our assumption concerning the participation in the absorption spectrum of 1-hydroxy-2,4-diacetylbenzene of the separate conjugated systems, we investigated a mixture of acetophenone and phenol and compared the results with the absorption spectra of 1-hydroxy-2,4-diacetylbenzene, acetophenone [5], and phenol [10] (Fig. 4, curve 2).

The comparison showed a significant increase in the intensity of the absorption bands of the mixture of acetophenone and phenol relative to the bands of pure acetophenone for the same type of spectra (Table 3).

TABLE 3

Position of Maxima of Absorption Bands

Compound	Region					
	Long-wave		Middle ultraviolet		Short-wave	
	λ	ε	λ	ε	λ	ε
1-Hydroxy-2,3-diacetylbenzene.	3250	3800	2860	16000	2360	51800
Mixture of acetophenone and phenol.	3200	109	2730	3800	2350	26300
Acetophenone.	3200	51	2805	923	2370	13180
Phenol.	—	—	2730	2140	—	—

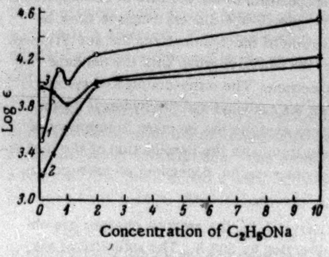


Fig. 7. Relation of absorption intensity to sodium ethylate concentration (in moles of C_2H_5ONa per mole of compound).
1) λ 3200 A, 1-hydroxy-2,4-diacetylbenzene,
2) λ 3550 A, 1,3-dihydroxy-4,5-diacetylbenzene,
3) λ 3100 A, methyl ether of 1,3-dihydroxy-4,6-diacetylbenzene

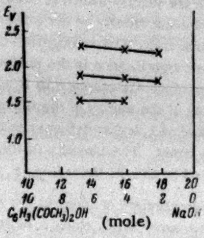


Fig. 9. Reduction potentials of the binary system $C_6H_3(COCH_3)_2(OH)$–NaOH.

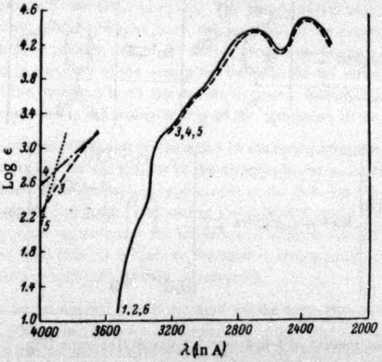


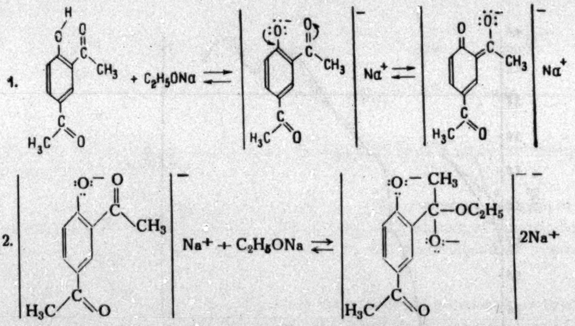
Fig. 8. Absorption spectra of 1-methoxy-2,4-diacetylbenzene.
1) in ethanol (10^{-2} - 10^{-5} M), 2) + 1000 moles H_2SO_4, 3) + 10 000 moles H_2SO_4, 4) + 10 000 moles H_2SO_4 after standing 3 days, 5) + 17 000 moles H_2SO_4, after neutralization, 6) + 17 000 moles H_2SO_4 after neutralization.

The intensity of the absorption bands of 1-hydroxy-2,4-diacetylbenzene is not the sum of the intensities of the corresponding bands of acetophenone and phenol. However, the spectrum of the mixture of acetophenone and phenol also is not strictly additive. The absorption spectrum of 1-hydroxy-2,4-diacetylbenzene must be considered as dependent chiefly on the ortho- and para-conjugated systems of the hydroxyl and the acetyl groups through the benzene ring. The conjugation of the acetyl group and of the hydroxyl group with the benzene ring itself also has some significance in the production of the absorption spectrum. The ortho-conjugated system is the most probable, since the presence in it of a hydrogen bond between the carbonyl and the hydroxyl groups leads to a lowering of the energy of the electron system. This hypothesis explains the increase in intensity of the long-wave band of 1,3-diacetylbenzene (dependent on ortho-conjugation with the introduction of the hydroxyl group) by 27.6 times. The intensity of the band in the middle ultraviolet region, dependent on para-conjugation, is increased by this 16 times (Fig. 1, curve 1) [17].

When sodium ethylate is added to the ethanol solution (Fig. 2, curves 1-8), the greatest changes are observed for the long-wave band, which is expanded in the long-wave direction by 500 A. The intensity of the band increases 12.5 times with 100 moles of sodium ethylate.

The absorption band that is present in the middle ultraviolet with up to 0.1 mole of sodium ethylate (Fig. 2, curves 1-6) is weakened, broadened, and then disappears, apparently as a result of a shift to the long-wave region.

The curve for the relation of the intensity of absorption of the line λ 3200 A in the spectrum of 1-hydroxy-2,4-diacetylbenzene to the concentration of sodium ethylate (Fig. 7, curve 1) shows a change in the region from 1 to 2 moles of sodium ethylate. This can be understood if we assume, as has been said previously [17], that reaction of the carbonyl group with the sodium ethylate is possible with the formation of a product of the hemi-acetal type [11]. The reaction proceeds in two stages.



From the ultraviolet absorption spectra of 1-hydroxy-2,4-diacetylbenzene (Fig. 2, curve 6) it is seen that the maximum change in absorption is at 2 moles of sodium ethylate to 1 mole of 1-hydroxy-2,4-diacetylbenzene. Around 1 mole of sodium ethylate a marked broadening of the bands is observed and the absorption tends to be continuous. This is evidence of a weak localization of ortho- and para-electron exchange in the molecule at the functional groups. When the amount of sodium ethylate is increased, the electron system of the molecule is differentiated and the selectivity of absorption becomes clear (Fig. 2, curves 6,7).

When the hydrogen bond is eliminated by ionization of the hydroxyl group, the ortho- and para-conjugated systems become equally probable. The absorption band at λ 2670 A, which depends on the absorption of the para-conjugated system, is shifted to the long-wave region, fuses with the absorption band in the long-wave region, which characterizes the ortho-conjugated system, and forms a new, high-intensity, broad band at λ 3175 A and ϵ 43 650.

Valyashko and Rozum [12], investigating 2- and 4-hydroxyacetophenones, showed that the intensity of the absorption bands is not changed when the concentration of sodium ethylate is increased and only a long-wave shift is observed. The same authors found [12] that in absorption spectra with small amounts of sodium ethylate a break is observed in the absorption curve upon dilution as a result of the alcoholysis of the sodium salt.

Our investigations of 1-hydroxy-2,4-diacetylbenzene have shown the absence of alcoholysis upon dilution of the ethanolic solutions of sodium ethylate, which is characteristic of the more distinct acid properties of the compound under investigation. The second acetyl group decreases the electron density of the benzene ring. As a result of this, there occurs a drawing away of the electrons from the hydroxyl oxygen and a weakening of the hydrogen bond with it. The ionization of the hydroxyl group is increased.

The changes in the absorption spectra of 1-hydroxy-2,4-diacetylbenzene upon addition of large amounts of sulfuric acid, which are expressed in a shift of the absorption to the long-wave region by 350 A, are the result, as in the case of 1,3-diacetylbenzene, of the formation of an oxonium salt [17]. The fact that the long-wave shift in absorption of 1,3-diacetylbenzene is less by 100 A under the same conditions may be due to the consumption of energy in breaking the hydrogen bond between the carbonyl and the hydroxyl groups.

The regularities observed in the shift of the absorption spectra of 1,3-diacetylbenzene under the influence of solvents of different dielectric permeability [17] also occur in the case of 1-hydroxy-2,4-diacetylbenzene (Fig. 1).

The curve for the absorption spectrum of 1-methoxy-2,3-diacetylbenzene in isooctane (Fig. 5, curve 2) differes from the curve for 1-hydroxy-2,4-diacetylbenzene in isooctane (Fig. 5, curve 1) in that there is a shift of the band in the middle ultraviolet region to the short-wave region by 220 A without change in intensity. The bend in the curve in the region of λ 3420-3300 A and ϵ 89-160 is the manifestation of an absorption band of diacetylbenzene previously overlapped by the broad band resulting from ortho-conjugation.

Methylation of 1-hydroxy-2,4-diacetylbenzene leads to breaking of the hydrogen bond between the carbonyl and the hydroxyl groups in the ortho-position. The energy of the electron system increases by 5.14 kcal/mole. With the elimination of the hydrogen bond, the possibilities for conjugation of the hydroxyl group with the carbonyl group in the para position and of the acetyl group with the benzene ring become greater, as is indicated by the increase in intensity of the absorption bands in the far ultraviolet region at λ 2660 A (Fig. 5, curve 2). Elimination of the hydrogen bond also results in greater stabilization of the π-electron system of the benzene ring, which is expressed in the strengthening of the absorption in the far ultraviolet region at λ 2330 A.

Investigation of 1-methoxy-2,4-diacetylbenzene in ethanolic solutions of sulfuric acid (Fig. 8) shows that the changes that occur in its spectra are similar to the changes in the absorption spectra of 1-hydroxy-2,4-diacetylbenzene, but less distinctly expressed. The decrease in the shift for 1-hydroxy-2,4-diacetylbenzene is a result of the effect of the hydrogen bond. The sum of the shift (570 A) in the absorption of 1-hydroxy-2,4-diacetylbenzene in the long-wave region under the influence of sulfuric acid (350 A) and the shift as a result of the effect of the hydrogen bond (220 A) is close to the shift in absorption of 1-methoxy-2,4-diacetylbenzene under the influence of sulfuric acid (600 A) (Fig. 8, curve 5).

The necessity for a larger amount of sulfuric acid for the formation of the oxonium salt of 1-hydroxy-2,4-diacetylbenzene (17 000 moles) than for the formation of the oxonium salt of 1-methoxy-2,4-diacetylbenzene (10 000 moles) is due to the fact that part of the sulfuric acid is spent in breaking the hydrogen bond.

Comparison of the absorption spectra of 1-methoxy-2,4-diacetylbenzene, 2,4-dimethoxyacetophenone [13], and 2- and 4-methoxyacetophenones (Table 4) shows a considerable similarity in the absorption spectra of the 1-methoxy-2,4-diacetylbenzene and 2,4-dimethoxyacetophenone and the presence in them of absorption bands that are found in the absorption spectra of 2- and 4-methoxyacetophenones.

The similarity of the absorption spectra of 1-methoxy-2,4-diacetylbenzene and 2- and 4-methoxyacetophenones permits us to assume, as in the case of 1-hydroxy-2,4-diacetylbenzene, the participation of 2- and 4-methoxyacetophenones in the absorption spectra of the first-named compound as a result of the separate conjugation of the methoxy group with the o- and p -acetyl groups.

TABLE 4

Position of Maxima of Absorption Bands

Compound	Region					
	Long-wave		Middle ultraviolet		Short-wave	
	λ	ε	λ	ε	λ	ε
1-Methoxy-2,4-diacetylbenzene.	3020	4000	2670	25000	2350	37000
2,4-Dimethoxyacetophenone	3010	9000	2670	12000	2280	14000
2-Methoxyacetophenone.	3045	5000	—	—	2475	8000
4-Methoxyacetophenone.	—	—	2745	18000	—	—

Polarographic investigation of 1-hydroxy-2,4-diacetylbenzene and its methyl ether.

The apparatus and method have been described previously [17]. Indications of [oxidation-reduction] processes were not detected in ethanol solutions, therefore the investigation was carriedout in aqueous solutions. The insoluble 1-methoxy-2,4-diacetylbenzene was not investgated.

1-Hydroxy-2,4-diacetylbenzene was investigated in molar ratios of this compound and sodium hydroxide of 1 : 2, 1 : 4, and 1.9 with a total concentration of $2\cdot10^{-2}$ M. The polarogram contains three waves, the potentials of which remain almost constant with a change in the amount of sodium hydroxide (Table 5). The composition-reduction potential curve contains no special point. The relationship is linear (Fig. 9).

TABLE 5

Changes in Reduction Potential of 1-hydroxy-2,4-diacetylbenzene in Relation to the Amount of Sodium Hydroxide

Concentration of components of the system ($\cdot 10^2$)		Reduction potentials in the region		
1-hydroxy-2,4-diacetylbenzene	Sodium hydroxide	1.6 V	1.9 V	2.3 V
0.66	1.34	1.54	1.90	2.33
0.4	1.6	1.56	1.89	2.27
0.2	1.8	—	1.85	2.26

The uniformity of the course of the composition-reduction potential curves is secured by the effect of the electron-donating hydroxyl group, which compensates for the deficiency of electrons on the carbon atom of the carbonyl group. The alkaline medium, which yields hydroxyl ions, facilitates the electron shift still more (see above, reaction 1).

The compensation of the electron density of the carbonyl carbon hinders the reduction process. The capacity for reaction with the sodium hydroxide is simultaneously decreased, and this also affects the magnitude of the reduction potential.

The hydroxyl group introduced into the molecular system of diacetylbenzene increases the possibility of intramolecular reaction of the system. In alkaline solutions, therefore, an intramolecular reaction of the two acetyl groups and the one hydroxyl group through the benzene ring is observed. The introduction of one hydroxyl group results in a rise in the reduction potential of 0.30 and 0.25 v (Table 6, Fig. 9).

Valyashko and Rozum [15], measuring the reduction potential of acetophenone and its ortho- and para-hydroxy derivatives, found a similar change in reduction-potential upon the introduction of a hydroxyl group into the benzene ring.

Compounds	Reduction potentials (in V)		
	First wave	Second wave	Third wave
1,3-Diacetylbenzene.	1.24	1.74	2.58
1-Hydroxy-2,4-diacetylbenzene	1.54	1.89	2.27

The hydroxyl group exerts a greater effect on the reduction potential of 1,3-diacetylbenzene than on the reduction potential of acetophenone [17]. The shift of electrons from the hydroxyl group through the benzene ring to the carbonyl carbon atom, with the electron density lowered by the effect of the acetyl group, naturally is distinctly indicated.

The relationship noted by Valyashko and Rozum [15], Nelson, Laitinen, and Mottus [14], Winkel and Proske [16], and us between the change in reduction potential and the shift in the corresponding maxima of the absorption bands is not observed in the case of the hydroxyl derivative of diacetylbenzene, possibly because of the more complex intramolecular reaction of more than two functional groups.

The introduction of a hydroxyl group into diacetylbenzene increases the possibility of electron exchange, especially in alkaline medium. As a result of this, the intramolecular reaction of the functional groups is strengthened and the intermolecular reaction of these groups with each other and with the solvent is suppressed. These changes appear in the absorption spectra in an increase in intensity of the absorption bands and an equalization of the probability of the absorption of the ortho- and para-conjugated systems (Fig. 2).

In the polarograms the change in the functional composition, as well as the changes in reduction potentials (Table 6), results in a weakening of the third wave, which appears especially distinct in 1,3-diacetylbenzene.

SUMMARY

1. The methyl ether of 1-hydroxy-2,4-diacetylbenzene, not previously described in the literature, has been synthesized.

2. A spectrographic investigation has been made of 1-hydroxy-2,4-diacetylbenzene and its methyl ether in ethanol, isooctane, and ethanolic solutions of sodium ethylate and sulfuric acid.

3. It has been found that 1-hydroxy-2,4-diacetylbenzene and its methyl ether give absorption spectra basically made up by the superposition of absorption bands of 2-hydroxyacetophenone and 4-hydroxyacetophenone and their methyl ethers.

4. The presence of a hydrogen bond has been established for the ortho-conjugated system and its energy has been calculated.

5. It has been found that in ethanolic solutions of sulfuric acid in amounts of not more than 1000 moles per mole of 1-hydroxy-2,4-diacetylbenzene or its methyl ether an oxonium salt is formed.

6. A polarographic investigation has been made of 1-hydroxy-2,4-diacetylbenzene and its methyl ether.

7. It has been established that there is a regular change in the reduction potential with the introduction of hydroxyl and methoxyl groups.

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* Russian translation.

SYNTHESIS OF N-SUBSTITUTED METHACRYLAMIDES

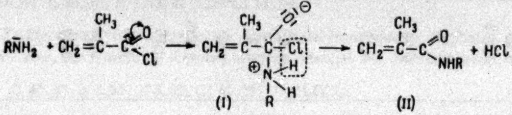
II. N-ARYLMETHACRYLAMIDES

T. A. Sokolova

Two methods of synthesizing N-substituted methacrylamides are given in the literature. One was developed for the preparation of small quantities of monomers and is based on organomagnesium compounds [1]; the other consists of reacting equimolecular amounts of the aromatic amine and methacrylyl chloride [2]. We used the second method.

Kinetic investigations of the acetylation of aromatic amines established the similarity between the mechanisms of this reaction and the electrolytic dissociation of amines [3-7]. The criteria for this similarity were the existence of a linear relation between the logarithms of the acetylation rate constant and the amine basicity constant [8,9].

Acetylation of amines with methacrylyl chloride, apparently, first formed an unstable compound (I). Then, a proton was split off from the nitrogen atom and formed a molecule of hydrogen chloride with a chlorine atom; as a result an N-substituted methacrylamide (II) was formed.



In examining the acetylation of amines with various reagents, it was seen that the rate depended on the rate of formation of the addition product of amine and acetylating agent. Further conversion of the addition product, however, did not affect the rate of the whole reaction. In the case of diketone [8] and maleic anhydride [9] this reduces to the intermolecular transfer of a proton; in the case of acetic anhydride - to the elimination of an acetic acid molecule; and in the case of methacrylyl chloride - to the elimination of hydrogen chloride. This similarity in the mechanism of the first stage of all these reactions leads to the following rule: acetylation with any acetylating agent occurs more readily the more labile the unshared electron pair of the nitrogen atom, i.e. the more basic the amine [10,11]. This conclusion is of practical importance; in the acetylation of amines it is necessary to consider first of all the degree of their basicity. Furthermore, in certain cases it is necessary to consider the nature of the acetylating agent. Thus in acetylating amines with methacrylyl chloride, hydrogen chloride is evolved and this can form a hydrochloride with the starting amine.

Due to this, as proved by an experimental check on the method described in the literature [2], the reaction of equimolecular amounts of amine and methacrylyl chloride gave small yields of amide. Good yields of N-substituted methacrylamides from amines, that are similar in degree of basicity to aniline ($K_{bas.}$ of the order of $10^{-9} - 10^{-11}$), were obtained by reacting 2 moles of amine with 1 mole of methacrylyl chloride in an organic solvent medium [see 12]. As we showed previously [13], it was advantageous to use a tertiary amine - dimethylaniline - as a binding agent for hydrogen chloride for less basic amines ($K_{bas.}$ of the order of 10^{-12}). As experiments showed, this method was also applicable to amines with even

Experiment No.	Name of N-substituted methacrylamide	Amounts of Reagents			Product Yield (in %)		Melting Point	Remarks
		amine (in moles)	acid chloride (in moles)	benzene (in ml)	crude	pure		
1	o-Methoxyphenylmethacrylamide	0.5	0.25	200	83.9	40.2	-	B.p. 141° at 2 mm
2	m-Ethoxyphenylmethacrylamide	0.195	0.195	200	98.9	66.13	95.5 - 96°	With 0.195 moles of dimethylaniline
3	o-Chlorophenylmethacrylamide	0.23	0.23	150	92.8	71.2	57	With 0.23 moles of dimethylaniline
4	Benzylmethacrylamide	0.29	0.29	200	74.3	45.9	83 - 83.5	With 0.29 moles of dimethylaniline
5	2,4,6-Trichlorophenylmethacrylamide	0.15	0.15	250	89.14	36.11	121-0-121.5	With 0.15 moles of dimethylaniline
6	Phenylmethacrylamide	2	1	400	94.4	61.1	85.0 - 85.5	-
7	p-Tolylmethacrylamide	0.4	0.2	150	88.3	71	88.0 - 88.5	-
8	m-Tolylmethacrylamide	0.4	0.2	140	91	68.4	78.0 - 78.5	-
9	o-Tolylmethacrylamide	0.4	0.2	125	86.3	62.8	94.5 - 95	-
10	p-Chlorophenylmethacrylamide	0.27	0.135	250	92.1	84.6	112 - 112.5	-
11	m-Chlorophenylmethacrylamide	0.3	0.15	250	99.2	33.1	105 - 105.5	-
12	p-Methoxyphenylmethacrylamide	1.5	0.75	230	76.5	44.5	90.5 - 91	
13	p-Ethoxyphenylmethacrylamide	0.54	0.27	175		58	107.5	
14	p-Nitrophenylmethacrylamide	0.17	0.17	40	65.7	50.8	150 - 151	
15	β-Naphthylmethacrylamide	0.18	0.17	60	75	37.6	138.5 - 139	
16	Cyclohexylmethacrylamide	0.34	0.17	100	87	75.4	111	
17	Phenylmethylmethacrylamide	0.6	0.15	150		10	60.5 - 61	
18	Diphenylmethacrylamide	0.15	0.15	140	94.5	33.92	105.5 - 106	With 0.15 moles of dimethylaniline
19	p-Bromophenylmethacrylamide	0.30	0.15	150		31.4	117.5 - 118	

lower basicity, such as trichloroaniline or diphenylamine ($K_{\text{bas.}}$ of the order of 10^{-14}) (table, experiments 5 and 18). But if $K_{\text{bas.}}$ of the starting amine is greater than $K_{\text{bas.}}$ of dimethylaniline ($K_{\text{bas.}25^\circ}$ $1.15 \cdot 10^{-9}$ [14]), then it competes with dimethylaniline in the reaction with hydrogen chloride, which results in a lower yield of the expected N-substituted methacrylamide. We observed this in the case of benzylamine, for example ($K_{\text{bas.}}$ of the order of 10^{-5}) (table, experiment 4). In such cases a more basic tertiary amine should be used, for example, triethylamine ($K_{\text{bas.}}$ of the order of 10^{-4}).

The conditions and results of the experiments are given in the table. The melting points of the reaction products were corrected.

EXPERIMENTAL

Preparation of N-substituted methacrylamides from amines with $K_{\text{bas.}}$ of the order of 10^{-9} - 10^{-11}. A solution of the amine (2 moles) in benzene was placed in a flask, fitted with a mechanical stirrer, a reflux condenser and a dropping funnel, and 1 mole of methacrylyl chloride was gradually added to the solution over 1.5 - 2 hours with very vigorous stirring. After heating for 1 hour at 70°, the benzene was steam distilled off. After cooling, the residue in the flask was filtered off on a Buchner funnel and washed with water to a neutral reaction. The dried product was recrystallized from aqueous alcohol. If the reaction product was a liquid, then after washing with dilute acid and then water, the oily layer (or its ether extract) was dried over anhydrous magnesium sulfate and distilled in vacuum.

Preparation of N-substituted methacrylamides from amines with $K_{\text{bas.}}$ of the order of 10^{-12} - 10^{-14} was carried out similarly, but in the presence of 1 mole of dimethylaniline instead of the second mole of the starting amine.

o-Chlorophenylmethacrylamide crystallized from aqueous alcohol in the form of colorless prisms. It was soluble in acetone, benzene, alcohol and dichloroethane, and insoluble in water.

Found %: C 61.79; H 5.22; N 7.11; Cl 18.04. $C_{10}H_{10}ONCl$.

Calculated %: C 61.33; H 5.12; N 7.16; Cl 18.16.

2, 4, 6 - Trichlorophenylmethacrylamide crystallized from aqueous alcohol in the form of prisms. It was insoluble in water, but soluble in acetone, benzene, alcohol and dichloroethane.

Found %: C 45.66; H 3.35; N 5.59; Cl 40.00. $C_{10}H_8OCl_3$.

Calculated %: C 45.37; H 3.03; N 5.29; Cl 40.26.

m-Ethoxyphenylmethacrylamide was soluble in acetone, benzene, alcohol and dichloroethane, and insoluble in water. It crystallized from aqueous alcohol as colorless needles.

Found %: C 70.39; H 7.49; N 6.72. $C_{12}H_5ON$.

Calculated %: C 70.25; H 7.32; N 6.83.

Benzylmethacrylamide crystallized from aqueous alcohol as colorless needles. It was insoluble in water, but soluble in acetone, benzene, alcohol and dichloroethane.

Found %: C 75.01; H 7.61; N 8.02. $C_{11}H_{13}ON$.

Calculated %: C 75.44; H 7.43; N 8.00.

o-Methoxyphenylmethacrylamide was a yellowish oily liquid with d_4^{20} 1.1018, n_D^{20} 1.5680. It was miscible with alcohol, acetone, benzene, ether, carbon tetrachloride and dichloroethane, and insoluble in water.

SUMMARY

1. A method for acetylation of amines of varying basicity with methacrylyl chloride, and giving good yields, was developed on the basis of a theoretical examination of the mechanism of amine acetylation.

2. Five N-substituted methacrylamides were prepared and characterized for the first time.

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* Original Russian pagination. See C. B. translation.

REACTIONS OF DIAZOAMINO COMPOUNDS

I. THERMAL DECOMPOSITION OF CARBOXY-SUBSTITUTED DIAZOAMINOBENZENE

A. I. Kizber* and V. A. Puchkov

In 1890 Heusler showed that heating diazoaminobenzene mixed with sand or paraffin up to 150-160° gave o- and p-aminodiphenyls in about 6% yield and a small amount of benzene and aniline [1]. In 1891 Hirsch thermally decomposed diazoaminobenzene in aniline and diazoaminotoluene in toluidine at 150° to obtain o- and p-aminodiphenyls and their corresponding methyl derivatives in 50% yield; small amounts of diphenylamine were detected [2,3]. Decomposition of diazoaminobenzene in phenol resulted in the formation of hydroxydiphenyl and diphenyl ether [4]. In 1930 Morgan and Walls thermally decomposed diazoaminotoluene to obtain, besides the o- and m-aminoditolylamines, about 1% of ditolylamine [5].

It follows from the data given that in heating diazoamino compounds (DAC) up to 150-160°, the main reaction products are aminodiphenyl derivatives; only traces of diphenylamine derivatives are formed. In 1954 one of us showed that on rapidly heating the dry dipotassium salt of diazoaminobenzene-4,4'-dicarboxylic acid (I) up to 270° without solvent, diphenylamine-4,4'-dicarboxylic acid (II) was formed in about 30% yield [6]. This suggested that it would be interesting to study the reactions of various samples of DAC at high temperatures. In this report we give the results of high temperature decomposition (HTD) in suitable solvents of (I) and some unsymmetrical diazoamino compounds. Using (I), we tested anthracene (b.p. 354°), acenaphthene (b.p. 278-279°), and octadecyl alcohol (b.p. 384°) as solvents. Analogous results were obtained in all three solvents, the yield of (II) was 55-65%; no reaction of the solvents with DAC was observed. In the HTD of potassium salts of 4'-chloro- and 4'-methyldiazoaminobenzene-4-carboxylic acid (III and IV) in solvents, the main reaction products were 4'-chloro- and 4'methyl-diphenylamine-4-carboxylic acids (V and VI), which are not described in the literature, in yields of about 30%. Among the reaction products of (III) we isolated a compound with the composition $C_{13}H_{10}O_2NCl$, which corresponded in its properties to an amino-chlor-diphenylcarboxylic acid, whose exact structure could not be determined as there was not enough of it. p-Aminobenzoic acid was also detected there in insignificant amounts. Besides (VI), we found in the products of the HTD of (IV) diphenylamine-4,4'-dicarboxylic acid and p-amino-benzoic acid. The structure of (VI) was proved by synthesis from p-bromobenzoic acid and p-toluidine. (II) was obtained from (VI) (after acetylation) by oxidation with potassium permanganate and subsequent hydrolysis. We could not obtain (V) from p-bromobenzoic acid or its methyl ether and p-chloroaniline. The synthesis of (V) was carried out starting with 4-nitro-4'-methyldiphenylamine [7]. In the HTD of the potassium salt of 1-cyclohexyl-3-(4'-carboxy-phenyl)-triazene (VIII) we were unable to isolate the expected N-cyclohexyl-p-aminobenzoic acid and found (II) in the reaction products.

We considered it interesting to measure the UV-absorption spectra of diphenylamine-4-carboxylic acid, acid (II), its dimethyl ester (IX), as well as the acids (V) and (VI) and the methyl ester of the latter (X) and to compare the data obtained with the UV-spectra of diphenylamine (see table).

The data in the table and Figs. 1 and 2 show that the introduction of a carboxyl group into position 4 of diphenylamine displaced the absorption maximum into the long-wave part of the spectrum by 30 mμ, the introduction of a second carboxyl group into position 4' caused further displacement of the absorption maximum by 20 mμ. The substitution of carboxyl by carbomethoxyl groups resulted in an even greater displacement of the absorption maximum which agreed with the stronger electron-acceptor properties of the carbomethoxyl group. The introduction into position 4' of diphenylamine-4-carboxylic acid of relatively weak electron-donor substitutents (Cl and CH_3) did not change the absorption maxima.

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*Deceased.

Compound	λ max. (mμ)	ε · 10⁴
Diphenylamine	285	0.395
Diphenylamine-4-carboxylic acid	315	0.509
(VI)	315	0.478
(V)	316	0.550
(X)	325	0.525
(II)	335	0.692
(IX)	346	0.940

EXPERIMENTAL

Diphenylamine-4,4'-dicarboxylic acid (II). To 54 g of anthracene at 275° was quickly added 10.8 g of the dipotassium salt of diazoaminobenzene-4,4'-dicarboxylic acid [prepared by neutralizing with potassium hydroxide and evaporating to dryness a solution of diazoaminobenzene-4,4'-dicarboxylic acid (m.p. 177-178°), which in its turn was prepared by treating 1 mole of p-aminobenzoic acid hydrochloride in aqueous solution at 20° with 0.5 mole of $NaNO_2$], the reaction mixture temperature rose to 295-300° and was kept at this level for 4-5 minutes. Then after cooling, the carefully ground mass was mixed with 150 ml of water and filtered, and 5.7 g of a substance with m.p. 290-295° was separated from the filtrate by acidification. For purification the latter was mixed with 250 ml of milk of lime (10 g of CaO) and the filtrate was acidified to give 4.75 g of (II) with m.p. 321-323° (322-324° [6]).

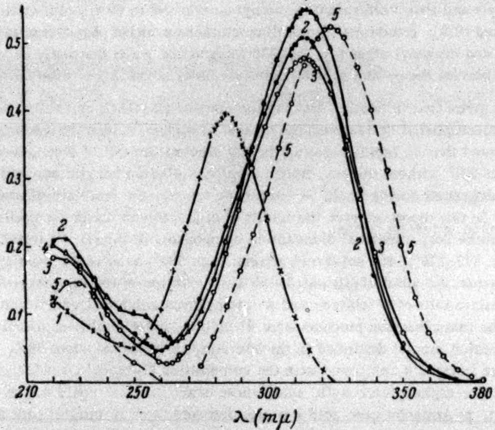

Fig. 1. Absorption spectra. 1) Diphenylamine, 2) diphenylamine-4-carboxylic acid, 3) 4'-methyl-diphenylamine-4-carboxylic acid, 4) 4'-chloro-diphenylamine-4-carboxylic acid, 5) methyl ester of 4'-methyl-diphenylamine-4-carboxylic acid.

From 1 g of (II) in methanol and dry HCl, we obtained 0.7 g of the dimethyl ester of diphenylamine-4, 4'-dicarboxylic acid (IX). After recrystallization from glacial acetic acid, it formed plates with m.p. 175.5-176.5°.

Found %: C 67.32, 67.51; H 5.10, 4.96; N 5.28, 5.12. $C_{16}H_{15}O_4N$.

Calculated %: C 67.40; H 5.26; N 4.92.

A mixed sample of the dimethyl ester of diphenylamine-4,4'-dicarboxylic acid (m.p. 175.5-176°) prepared from (II), and that prepared by oxidizing 4,4'-dimethyldiphenylamine, melted at 175-175.5°.

From 1 g of (II) in anhydrous ethyl alcohol and dry HCl, we obtained 0.55 g of the diethyl ester. After recrystallization from 60% acetic acid, it formed needles with m.p. 117-117.5°.

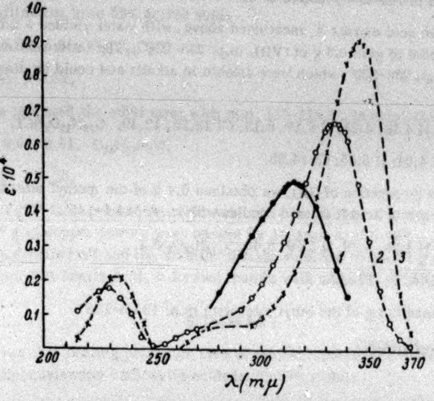

Fig. 2. Absorption spectra. 1) Diphenylamine-4-carboxylic acid, 2) diphenylamine-4,4'-dicarboxylic acid, 3) dimethyl ester of diphenylamine-4,4'-dicarboxylic acid.

Found %: N 4.58, 4.75. $C_{18}H_{19}O_4N$. Calculated %: N 4.47.

Diphenylamine-4'-chloro-4-carboxylic acid (V). Preparation by decomposition of 4'-chlorodiazoaminobenzene-4-carboxylic acid (III). A solution of 0.1 mole of p-carboxyphenyldiazonium (pH 4-4.5) was added to a solution of 0.1 mole of p-chloroaniline in 50 ml of methyl alcohol. The precipitate was filtered off and washed with water and alcohol to give 21 g of (III). After recrystallization from ethyl acetate, the light yellow crystals had m.p. 169-169.5° (decomp.).

0.2988 g of substance: 11.10 ml of 0.1 N NaOH.

Found %: COOH 17.10. Calculated for (III) %: COOH 16.34.

By neutralization with the calculated amount of potassium hydroxide and subsequent evaporation to dryness, we obtained the potassium salt of (III). 11.8 g of the latter was quickly added to 55 g of octadecyl alcohol, heated to 275°; there was vigorous evolution of gases and heating up to 290°. The temperature was kept at this value for 3-4 minutes, and after cooling the mass was ground and extracted with water. Acidification of the water extract gave a precipitate, which was extracted several times with 15% hydrochloric acid (extract A) until a light yellow precipitate no longer separated on diluting the hydrochloric acid extract with water. The material, which was insoluble in hydrochloric acid (about 3.8 g) was heated with 1000 ml of milk of lime (5 g of CaO), filtered and acidified to give 3.2 g of a substance with m.p. 199-200°; by recrystallization from 80% acetic acid, we obtained 2.2 g of (V) - lenticular crystals with m.p. 204-205°.

Found %: Cl 14.30; 14.51; N 5.59, 5.50. $C_{13}H_{10}O_2NCl$.

Calculated %: Cl 14.35; N 5.65.

On standing, the mother liquor yielded a further 0.5 g of (V) with m.p. 203-204°. After separating the latter, p-aminobenzoic acid remained in the mother liquor. By diazotization and coupling with β-naphthol, we obtained a dye, which was recrystallized from acetic acid to give interlaced needles with m.p. 298-299°. A mixture with the dye prepared from pure p-aminobenzoic acid and β-naphthol (m.p. 300°) melted at 298-299°.

(V) was soluble in concentrated hydrochloric acid (d 1.18). A solution of (V) in concentrated sulfuric acid was colorless, but became yellow on adding nitric acid. On heating (V) above its melting point, it decarboxylated to form 4-chlorodiphenylamine, m.p. 72° (70-71° [8]). A mixture of (V) with diphenylamine-4'-chloro-4-carboxylic acid (m.p. 205-206°) melted at 204-205°.

Dilution of the hydrochloric acid extract A, mentioned above, with water yielded a substance, which was recrystallized from 85% alcohol to give 0.3 g of (VII), m.p. 235-236°. The latter sublimed in the form of lemon yellow needles with m.p. 238-239°, which were soluble in alkalis and could be diazotized and coupled.

Found %: C 62.97, 62.96; H 4.18, 4.25; N 6.17, 6.13; Cl 13.25, 13.49. $C_{13}H_{10}O_2NCl$.

Calculated %: C 63.10; H 4.04; N 5.65; Cl 14.35.

By a method similar to the preparation of (IX), we obtained 0.4 g of the methyl ester from 0.5 g of (V). After recrystallization from 60% acetic acid it formed needles with m.p. 144.5-145°.

Found %: C 64.61, 63.87; H 4.50, 4.66; N 5.59, 5.40. $C_{14}H_{12}O_2NCl$.

Calculated %: C 64.20- H 4.59; N 5.35.

From 0.5 g of (V) we obtained 0.3 g of the ethyl ester with m.p. 134.5-135°.

Found %: N 4.76, 4.92. $C_{15}H_{14}O_2NCl$.

Calculated %: N 5.08.

Preparation of (V) from 4-nitro-4'-methldiphenylamine. 16 g of 4-nitro-4'-methyldiphenylamine with m.p. 136-137° (prepared by heating 4-nitro-chlorobenzene-2-sulfonic acid with p-toluidine and subsequently desulfonating the 4-nitro-4'-methyl-diphenylamine-2-sulfonic acid [9]) was boiled with 50 ml of glacial acetic acid and 60 ml of acetic anhydride. We obtained 14.2 g of 4-nitro-4'-methyl-acetyldiphenylamine, which melted at 113-114° after recrystallization from propyl alcohol. 13.5 g of this product, 750 ml of water, and 15.8 g of potassium permanganate were heated for 4 hours at 95° in a stream of CO_2, filtered, evaporated to 250 ml, and acidified to give 8.5 g of 4'-nitro-N-acetyldiphenylamine-4-carboxylic acid; after recrystallization from 60% acetic acid, it formed prisms with m.p. 239°. 1.5 g of the crystals was reduced with zinc dust in a mixture of 50 ml of hydrochloric acid (d 1.18) and 150 ml of 35% acetic acid, filtered, and 10 ml of 0.5 N sodium nitrite added to the filtrate. 100 ml of hydrochloric acid (d 1.18) and 3 g of cuprous chloride were added to the solution of the diazo compound. After heating for 2 hours at 60°, the 4'-chloro-N-acetyl-diphenylamine-4-carboxylic acid was filtered off and hydrolyzed to (V) by boiling in 6% potassium hydroxide. After recrystallization from 80% acetic acid, we obtained 0.6 g of lenticular crystals with m.p. 205-206°.

Found %: N 5.79, 5.70. $C_{13}H_{10}O_2NCl$.

Calculated %: N 5.65.

Diphenylamine-4'-methyl-4-carboxylic acid (VI). Preparation of (VI) by decomposition of the potassium salt of 4'-methyldiazoaminobenzene-4-carboxylic acid (IV). To 50 g of anthracene at 270° was added 10.2 g of (IV) (prepared by neutralizing with potassium hydroxide and evaporating to dryness 4'-methyldiazoaminobenzene-4-carboxylic acid with m.p. 163°, prepared similarly to (III), by coupling p-carboxyphenyldiazonium with p-toluidine). There was vigorous evolution of gases and heating up to 290°. The temperature was kept at this value for 3-4 minutes, then the reaction mass was cooled, ground, and extracted with water and the water extract acidified. Substance A was filtered off (filtrate B). Substance A was mixed with concentrated hydrochloric acid and filtered (insoluble residue C). Dilution of the hydrochloric acid filtrate with water gave a precipitate, which was recrystallized from 60% acetic acid to yield 2 g of (VI), m.p. 180-181°. After recrystallization from 80% alcohol, it formed rhombs with m.p. 185-186°. A mixture with (VI) prepared from p-bromo-benzoic acid and p-toluidine melted at 185-186°.

Found %: C 73.42, 73.45; H 5.68, 5.64; N 6.00, 6.17. $C_{14}H_{13}O_2N$.

Calculated %: C 74.0; H 5.73; N 6.16.

The aromatic amine contained in the filtrate B was diazotized and coupled with β-naphthol (pH 9), filtered, and the dye salted out of the filtrate. After crystallization from glacial acetic acid it had m.p. 300° and weighed 0.9 g. A mixture with the dye from p-aminobenzoic acid and β-naphthol melted at 299-300°. The precipitate C, mentioned above, was treated with milk of lime and acidification of the filtrate gave a substance, from which we obtained 0.8 g of (II) with m.p. 323-324° after washing with 80% acetic acid. From (VI) in methanol and dry HCl, we obtained the methyl ester (X) with m.p. 123.5-124.5°, which had m.p. 124.2-124.7° after crystallization from 50% acetic acid.

Found %: N 5.86, 5.85. $C_{15}H_{15}O_2N$.

Calculated %: N 5.82.

Similarly, we prepared the ethyl ester with m.p. 115-115.5°, in ethyl alcohol.

Found %: N 5.61, 5.61. $C_{16}H_{17}O_2N$.

Calculated %: N 5.50.

Preparation of (VI) from p-bromobenzoic acid and p-toluidine. 5 g of p-bromobenzoic acid, 30 g of p-toluidine and 2.5 g of copper powder were heated for 15 hours at 175-180°. After making alkaline, the toluidine was steam distilled off and the alkaline filtrate acidified to give 1 g of (VI), m.p. 181-182.5°. After recrystallization from 60% acetic acid, it formed rhombs with m.p. 185.5-186.5°.

SUMMARY

1. It was shown that heating potassium salts of diazoaminobenzene carboxylic acids to 270-290° gave the corresponding diphenylamine carboxylic acids in 30-65% yields.

2. We measured the UV-spectra of the diphenylamine carboxylic acids synthesized and of their methyl and ethyl esters.

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BROMINATION OF ETHYL CYCLOPENTANONE-2-CARBOXYLATE AND SOME OF ITS DERIVATIVES

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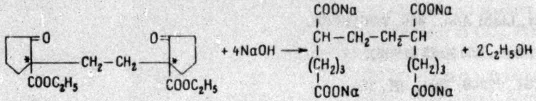
We observed previously [1] that diethyl ethane-α-β-dicyclopentanonedicarboxylate (m.p. 104-106°) isolated from the 135-201° (1 mm) fraction was formed in the reaction between the potassium derivative of ethyl cyclopentanonecarboxylate and dibromoethane.

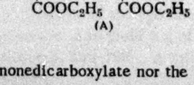
After removal of the liquid fraction from the separation of the above-mentioned diketoester, a 170-199° (1 mm) fraction was obtained which was subjected to acid cleavage [2]. As a result, the isolated acid (m.p. 132.5-134°) was identified as 1,4,7,10-decanetetracarboxylic acid. The latter is probably formed according to the reaction



Since the diketoester contains two asymmetric carbon atoms, and considering the symmetrical structure of the molecule, one could infer the existence of two isomers in addition to the product having m.p. 104-106°, and the formation of a tetracarboxylic acid upon the opening of the rings would be expected. An analogous transformation in the heterocyclic series was observed by Woodward and Eastman [3].

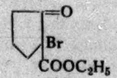
Upon bromination of the sodium or potassium derivatives of ethyl cyclopentanonecarboxylate, we obtained the bromo derivative together with the original β-ketoester.

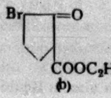
Because the yield of ethyl diacetylsuccinate considerably increases upon bromination of the magnesium derivative of acetoacetic ester [4], we used this reaction for synthesis of the diketoester having structure (A).

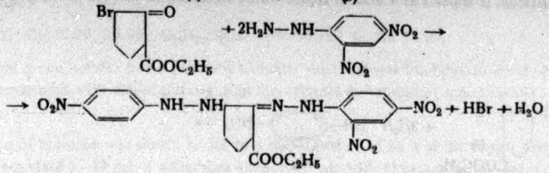


(A)

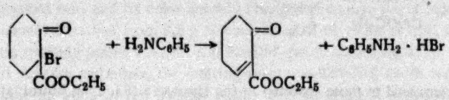
However, neither ethyl dicyclopentanonedicarboxylate nor the magnesium derivative formed under the conditions shown by the authors. It was thought that the reactivity could be enhanced by reacting bromine with the copper salt of ethyl cyclopentanonecarboxylate, but the resulting ethyl bromocyclopentanonecarboxylate isolated as the 2,4-dinitrophenylhydrazone was identical with a previously known one (according to a mixed m.p. test). In order to determine the structure of the bromoketone (i.e., the position of bromine), we carried out bromination of ethyl cyclopentanonecarboxylate in a manner similar to the bromination of ethyl cyclohexanonecarboxylate [5]. The resulting bromo derivative gave a bluish-violet color with ferric chloride and was precipitated by alkali solutions. On this basis we concluded that the γ-isomer (b), and not its α-bromo analog (a), was formed. The location of the halogen close to the keto group caused increased reactivity, which was observed in the reaction between the bromo derivative of ethyl cyclopentanonecarboxylate and 2,4-dinitrophenylhydrazine.


(a)

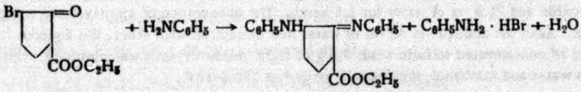

(b)



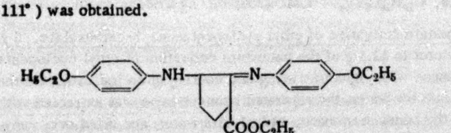
Kotz and Grethe [6] synthesized the unsaturated ketoester by a reaction of aniline on ethyl α-bromo-cyclopentanonecarboxylate according to the following scheme



Using this reaction with ethyl γ-bromocyclopentanonecarboxylate, we obtained a liquid which polymerized rapidly and could not be distilled at 1 mm pressure. When the above reaction was carried out in the absence of solvent, a dark brown tarry mass was obtained, from which (by means of ether extraction) a colorless crystalline substance (m.p. 99-100.5°) was separated; this was insoluble in water, but soluble in acids (upon heating). The absence of halogen and of a keto group led us to suspect the formation of a Schiff base (syntheses of Schiff bases from Dieckmann esters are widely described in the literature [7]).

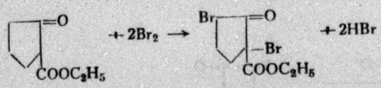


p-Phenetidin reacted in an analogous manner, but more vigorously, and 50% yield of the condensation product (m.p. 109.5-111°) was obtained.

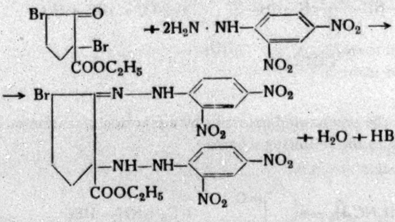


In order to prove the structures of the compounds obtained, we treated them with hydrochloric acid and sodium nitrite; subsequently they were mixed with an alkaline solution of β-naphthol and orange-red azo-dyes were formed.

Further studies of the reaction characteristics of ethyl cyclopentanonecarboxylate showed that this compound is easily brominated (similarly to acetoacetic ester) and forms a dibromo derivative according to the equation



After vacuum distillation it appears as a viscous liquid which easily forms di-(2,4-dinitrophenyl)-hydrazidohydrazone.



The results obtained correspond to those reported in the literature [8]; upon bromination of acetoacetic ester, 3 hydrogen atoms are replaced by bromine. In our case only 2 hydrogen atoms were replaced because of the activating influence of the carbonyl group and the presence of a bromine on a carbon atom in the alpha position to the carboxyl group. Because of tar formation upon ketone and acid cleavage, the position of halogens in ethyl dibromocyclopentanonecarboxylate remains undetermined.

EXPERIMENTAL

1, 4, 7, 10-Decanetetracarboxylic acid. 15.2 g of the substance having b.p. 170-199°, and obtained after the separation of diethyl ester of ethane-α-β-dicyclopentanonedicarboxylic acid was heated with 31.3 g of 30% sodium hydroxide and 21.9 ml of water for 1.5 hours. The appearance of an oily layer was observed after only 5 minutes. After the addition of 45 ml of water and extraction with ether, the aqueous layer was acidified with 12 ml of concentrated sulfuric acid; 9.5 g of light yellow crystals was obtained. Upon recrystallization from water and methanol, the crystals melted at 132.5-134°.

Found %: C 52.53, 52.37; H 7.00, 7.25. $C_{14}H_{22}O_8$. Calculated %: C 52.81; H 6.98.

Found %: Ag 55.8, 55.9. $C_{14}H_{18}O_8Ag_4$. Calculated %: Ag 57.8.

Bromination of the potassium derivative of ethyl cyclopentanone-2-carboxylate. 3 g of bromine was added over a period of 30 minutes to 11.1 g of the potassium derivative of ethyl cyclopentanonecarboxylate [1] in 30 ml of anhydrous benzene with vigorous stirring and cooling in an ice bath. On the next day the reaction mixture was poured into ice water, the separated benzene layer was extracted with ether, the ether extracts were combined with the benzene solution, washed with water, and dried over anhydrous sodium sulfate. The solvents were removed in vacuo at temperature not exceeding 40° and the residue was distilled. The following fractions were obtained: 1st 70-77°, 2.54 g n_D^{20} 1.4693; 2nd 94-99°, 0.90 g, n_D^{20} 1.4963; 3rd 94-100°, n_D^{20} 1.5100; tars 3 g. Each fraction was worked up with 2,4-dinitrophenylhydrazine solution and the following results were obtained: 1st fraction yielded a yellow precipitate of 2,4-dinitrophenylhydrazone (m.p. 125-127° after recrystallization from a mixture of ethanol and ethyl acetate), and no melting point depression was observed when mixed melting point with 2,4-dinitrophenylhydrazone of ethyl cyclopentanonecarboxylate was determined; 2nd and 3rd fractions yielded bright red dinitrophenyl-hydrazones which were recrystallized from a mixture of ethyl acetate and ether and melted at 231° (with decomposition). They did not show any melting point depression when mixed melting points were determined with the 2,4-dinitrophenylhydrazone of ethyl bromocyclopentanonecarboxylate.

Bromination of the copper derivative of ethyl cyclopentanone-2-carboxylate. a) Copper derivative of ethyl cyclopentanone-2-carboxylate. A solution of 12.6 g of cupric acetate in 200 ml of water was slowly added to the mixture of 17.7 g of ethyl cyclopentanonecarboxylate (b.p. 78-81° at 3 mm) and 9 ml of ether; after neutralization with a 5% solution of sodium hydroxide the precipitate was filtered off, washed with water and dried at 120-130°. 32.7 g (77.3% of the solid was obtained; copper content was determined gravimetrically.

Found %: Cu 16.99, 16.98. $C_{16}H_{22}O_6Cu$. Calculated %: Cu 17.02.

The light green powder had a pleasant aromatic odor and was insoluble in water, ether, and chloroform. Upon treatment with dilute sulfuric acid the original β-ketoester (m.p. 181-183°) and cupric sulfate were formed.

b) 7.2 g of bromine was slowly added to a suspension of 16.36 g of the copper derivative of ethyl cyclopentanonecarboxylate in 42 ml of anhydrous dichloroethane with vigorous stirring and cooling in an ice bath. The separated cupric bromide and unreacted copper derivative were filtered off, washed with dichloroethane and the filtrate was washed with water, dried over anhydrous sodium sulfate and distilled. Two fractions were obtained: 97-98° (1 mm), 2.04 g, n_D^{20} 1.4880; 98-108° (1 mm), 11.6 g, n_D^{20} .4948. The latter was a light-yellow liquid fuming in air and containing a halogen (Beilstein test). Upon treatment with sodium hydroxide, a white precipitate separated out, and its color quickly changed to brown; ferric chloride gave a violet color. 2,4-Dinitrophenylhydrazones obtained from 0.5 g of each fraction in yields of 0.41 and 0.44 g, respectively, were red powders having melting points 92-133° and 93-136° (with decomposition). After recrystallization from a mixture of ethyl acetate and ether, the melting point was 230-231° (with decomposition). No melting-point depression was observed when mixed melting points were determined with 2,4-dinitrophenylhydrazone of ethyl monobromocyclopentanonecarboxylate.

Bromination of ethyl cyclopentanonecarboxylate. 9 g of bromine was slowly added to 7.3 g of ethyl cyclopentanone-2-carboxylate-1 (b.p. 112-114° at 15 mm) with stirring and cooling; during the addition vigorous liberation of hydrogen bromide and the disappearance of bromine color were observed. After passing of a current of dry carbon dioxide and distillation, 11.2 g of a substance having b.p. 104-106° (1.5 mm) was obtained; after second distillation 7.7 g of a substance with b.p. 104-106° (1.5 mm) was obtained. Yield 69.3%. Light-yellow, extremely hygroscopic liquid, constantly splitting off hydrogen bromide and turning a dark color. Upon the addition of a 40% solution of potassium hydroxide, a white precipitate separated out; alcoholic solution of ferric chloride was turned a violet color.

d_4^{20} 1.4477, n_D^{20} 1.5140, MR_D 48.89; calculated 46.37.

Found %: C 43.76, 43.81; H 5.03, 5.37; Br 32.76, 32.08. $C_8H_{11}O_3Br$.

Calculated %: C 40.87; H 4.72; Br 33.98.

0.69 g of ethyl bromocyclopentanonecarboxylate in 30 ml of alcohol and 1.17 g of 2,4-dinitrophenylhydrazine yielded 0.75 g of 2,4-dinitrophenylhydrazone, which was a reddish-orange powder when recrystallized from a mixture of ethyl acetate and ether melting at 230° (with decomposition).

Found %: N 21.52, 21.57. $C_{20}H_{20}O_{10}N_8$. Calculated %: N 21.05.

Reaction of ethyl bromocyclopentanonecarboxylate with aniline. a) 45.7 g of aniline was slowly added to 30.49 g of ethyl bromocyclopentanonecarboxylate in 155 ml of ether; during the addition separation of a precipitate (aniline bromohydrate) was observed. After boiling (10 minutes) on a steam bath the reaction mixture was left standing overnight. Then it was transferred to a solution of 48 g of oxalic acid in 610 ml of water and steam distilled. The distillate was extracted with ether and the ether extracts dried over anhydrous sodium sulfate. Upon the removal of ether the residue, a dark colored liquid, rapidly polymerized and all attempts to distil it in vacuo (at 1 mm) were unsuccessful.

b) 63.7 g of aniline was slowly added to 15.95 g of ethyl bromocyclopentanonecarboxylate with stirring and cooling. The mixture was acidified (to congo red) with hydrochloric acid, and the separated oily product was extracted with ether. The ether extracts were washed with sodium bicarbonate solution, then with water and dried over anhydrous sodium sulfate. After the removal of ether from the filtrate, 12.5 g of dark brown tarry residue was extracted with a small amount of ether. Upon filtration and washing with ether 3.21 g of yellowish crystals was obtained. When recrystallized from methanol (in the presence of activated charcoal) the crystals melted at 99-100.5°. Additional 0.68 g was obtained from mother liquor; a total of 3.89 g of solid was isolated. Colorless needles, insoluble in water, slightly soluble in ethanol, more soluble in hot ethanol. Absence of halogen and no color reaction with ferric chloride. An aqueous suspension of the solid did not decolorize potassium permanganate solution (weak decolorization could be noted in an acetone solution). The presence of nitrogen was demonstrated by the Lassaigne test, no precipitate was observed upon treatment with a 2,4-dinitrophenylhydrazine solution.

Found %: C 74.46, 74.67; H 7.24, 7.12; N 8.56, 8.42. $C_{20}H_{22}O_2N_2$.

Calculated %: C 74.49; H 6.83; N 8.69.

Under analogous conditions 6 ml of aniline was added to 11.83 g of ethyl bromocyclopentanonecarboxylate; the separated precipitate was washed with ether and dried. Qualitative tests (reaction for bromide ion, separation of aniline under the influence of sodium hydroxide solution, diazotization) proved that the precipitate was aniline bromohydrate.

Reaction of ethyl bromocyclopentanonecarboxylate with p-phenetidin. 76.5 g of freshly distilled p-phenetidin was added to 19.1 g of ethyl bromocyclopentanonecarboxylate with cooling and vigorous stirring. The reaction mixture was poured into water and acidified with hydrochloric acid; the separated precipitate was washed with water and ether. 13.38 g (50.75%) of solid was obtained, m.p. 109.5-111°. Light-yellow needles (after recrystallization from ethanol).

Found %: C 70.40, 70.70; H 7.09, 7.25; N 7.18, 7.13. $C_{24}H_{30}O_4N_2$.

Calculated %: C 70.20; H 7.38; N 6.83.

Ethyl dibromocyclopentanonecarboxylate. 8 Ml of bromine was slowly added to 5.45 g of ethyl cyclopentanone-2-carboxylate-1 with cooling and stirring (the liberated HBr was absorbed in a solution of sodium hydroxide); then carbon dioxide was bubbled through the reaction mixture for 3 hours. 8.25 g of substance having boiling point 133-134° (2 mm) was obtained. Yield 74.6%. Yellow liquid gradually liberating hydrogen bromide and turning a more intense color. The dibromide gave a positive halogen test and was not colored violet by an alcoholic solution of ferric chloride.

d_4^{20} 1.8862, n_D^{20} 1.5490; MR_D 53.70; calculated 54.14.

Found %: Br 50.31, 49.83. $C_8H_{10}O_3Br_2$. Calculated %: Br 50.88.

0.4 g of 2,4-dinitrophenylhydrazine was added to 0.5 g of ethyl dibromocyclopentanonecarboxylate in 20 ml of ethanol; 0.29 g of cherry-red solid was obtained which melted at 285° (with decomposition) after recrystallization from ethyl acetate and gave a positive halogen test.

Found %: Br 13.03, 13.34; N 18.94, 18.67. $C_{20}H_{19}O_{10}N_8Br$.

Calculated %: Br 13.07; N 18.33.

SUMMARY

1. 1, 4, 7, 10-Decanetetracarboxylic acid was isolated through acid cleavage of fraction 170-199° (1 mm) separated during condensation of the potassium derivative of ethyl cyclopentanonecarboxylate with dibromoethane and the mechanism of its formation was postulated.

2. It was found that ethyl bromocyclopentanonecarboxylate is formed upon the action of bromine on metal derivatives of ethyl cyclopentanonecarboxylate. Ethyl bromocyclopentanonecarboxylate is also formed upon bromination of ethyl cyclopentanonecarboxylate.

3. It was demonstrated that ethyl bromocyclopentanonecarboxylate condenses with primary amines (aniline, p-phenetidin) with the formation of tricyclic Schiff bases.

4. It was established that upon bromination of ethyl cyclopentanonecarboxylate with excess bromine the formation of dibromo derivative of the above ester takes place.

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* Original Russian pagination. See C. B. translation.

A NEW METHOD FOR THE PREPARATION OF ANTIMONIOAROMATIC COMPOUNDS

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A series of methods for synthesizing antimonioaromatic compounds are known at the present time.

1. These compounds may be prepared through organomagnesium reagents [1] and, by the method used by Michaelis [2], namely treating suitable mixtures of halogen derivatives with sodium. These methods mainly result in tertiary stibines.

2. The reaction of stibine halides with mercurioaromatic compounds gave secondary and tertiary derivatives [3].

3. The Schmidt reaction (the reaction of aryldiazoniums with sodium antimonite) [4] and the Scheller reaction (the reaction of an aryldiazonium in an acidic medium with antimony trichloride in the presence of copper salts) [5] gave primary arylantimonous acids.

4. Antimonioaromatic compounds may be prepared by the diazo method of A. N. Nesmeyanov and K. A. Kocheshkov [6].

In the last case reaction of a suspension of May's salt ($ArN_2Cl \cdot SbCl_3$) in acetone or in ethyl acetate with zinc dust gave a mixture of primary, secondary and teriary products. In their subsequent papers, Nesmeyanov et al. modified this method so as to obtain mainly secondary derivatives [7].

5. Waters [8] obtained mainly triarylstibines (as well as diarylstibines in isolated cases) by treating metallic antimony powder with a diazonium salt in anhydrous acetone or ethyl acetate in the presence of chalk.

The successful work on preparing arsenoaromatic compounds by oxidizing arylhydrazines with arsenic acid [9] prompted us to attempt the preparation of antimonioaromatic compounds by an analogous method. However, these attempts gave negative results. This may be explained, on the one hand, by the low solubility of antimonic and arylantimonic acids in water and in organic solvents and, on the other, by the considerably lower oxidizing power of antimonic as compared with arsenic acids.

Therefore, we decided to try reacting arylhydrazines with antimony trichloride in hydrochloric acid solutions, using aerobic oxygen as oxidant in the presence of cupric chloride. Finally, we arrived at the following procedure. We added phenylhydrazine to a hydrochloric acid solution of antimony trichloride and cupric chloride. Air was passed through the reaction mixture, which was stirred; the mixture formed a precipitate. Treatment of the precipitate with acetone caused the evolution of nitrogen and diphenylantimonic acid was precipitated on adding water. When treated with concentrated hydrochloric acid, this acid formed a trichloride, which when reduced with sulfur dioxide gave diphenylstibine chloride. Ammonium chloride was added to the filtrate from the precipitate formed by passing air. This precipitated a double compound $C_6H_5SbCl_4 \cdot NH_4Cl$, which, when hydrolyzed, gave phenylantimonic acid, and when the latter was reduced with sulfur dioxide in a hydrochloric acid medium it gave phenyldichlorostibine.

Thus the method described by us made it possible to prepare simultaneously primary and secondary aromatic stibines. Considering the mechanism proposed by one of us [10] for the formation of organometallic compounds by a diazo reaction, the course of the reaction of phenylhydrazine and antimony trichloride may be described in the following way. The paper referred to showed that the formation of arseno-

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* Deceased.

and antimonioaromatic compounds by a diazo reaction passed through intermediate complexes of the type $ArN_2X \cdot MeX_3$*, and the primary products were obtained from those complexes in which the metal was not bound to the aromatic radical (primary complex)

$$ArN_2X \cdot Me^{n}X_m \rightarrow ArMe^{n+2}X_{m+1} + N_2$$

(n - metal valency, m - number of halide atoms or hydroxyl groups on the metal.)

The secondary products were prepared from complexes which had already one radical on the metal (secondary complex).

$$ArN_2X \cdot ArMe^{n}X_{m-1} \rightarrow Ar_2Me^{n+2}X_m + N_2$$

Tertiary products were prepared from complexes which had two radicals on the metal (tertiary complex).

$$ArN_2X \cdot Ar_2Me^{n}X_{m-2} \rightarrow Ar_3Me^{n+2}X_{m-1} + N_2$$

As noted in the paper referred to, all these reactions proceeded without the formation of free radicals (particles kinetically independent of each other). Apparently, the active complex in these reactions was formed directly from the molecules, i.e, missing out the stage of free radical formation.

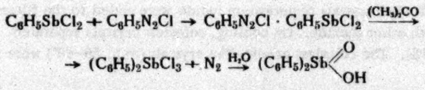
The formation of antimonioaromatic compounds by our method may be described in the following way. Phenylhydrazine (hydrochloride) was oxidized with aerobic oxygen to phenyldiazonium chloride; the latter gave May's salt with antimony trichloride

$$C_6H_5NHNH_2 \cdot HCl + SbCl_3 + O_2 \xleftarrow{CuCl_2} C_6H_5N_2Cl \cdot SbCl_3 + 2H_2O$$

Another phenylhydrazine molecule reduced May's salt and was oxidized to phenyldiazonium chloride

$$C_6H_5NHNH_2 \cdot HCl + 2C_6H_5N_2Cl \cdot SbCl_3 \rightarrow C_6H_5N_2Cl + 2C_6H_5SbCl_2 + 2N_2 + 4HCl$$

Phenylstibine chloride formed a secondary complex with phenyldiazonium chloride



$$C_6H_5SbCl_2 + C_6H_5N_2Cl \rightarrow C_6H_5N_2Cl \cdot C_6H_5SbCl_2 \xrightarrow{(CH_3)_2CO}$$
$$\rightarrow (C_6H_5)_2SbCl_3 + N_2 \xrightarrow{H_2O} (C_6H_5)_2Sb\begin{matrix}\nearrow O \\ \searrow OH\end{matrix}$$

Cupric chloride, of which there was an excess in the solution, oxidized phenylstibine chloride to phenylstibine tetrachloride; the latter gave a double compound ($C_6H_5SbCl_4 \cdot NH_4Cl$), with ammonium chloride, which, when hydrolyzed, gave phenylantimonic acid. As diphenylstibine chloride is practically insoluble in a hydrochloric acid medium, it did not give a tertiary complex with diazonium chloride. This is probably the reason why in our method tertiary stibines were not detected in the reaction mixtures.

O. A. Reutov and O. A. Ptitsyna, in their latest paper [11], expressed doubts on the possibility of preparing double compounds of the type $ArN_2Cl \cdot ArSbCl_2$ and $ArN_2Cl \cdot Ar_2SbCl$ by the direct reaction of aryldiazonium chlorides with arylstibine chlorides. Our numerous experiments [12] have shown that under our conditions the complexes, corresponding to the compositions $ArN_2Cl \cdot ArSbCl_2$, $ArN_2Cl \cdot Ar_2SbCl$, $(ArN_2Cl)_2 \cdot \cdot ArSbCl_2$, are readily prepared and that these reactions are similar in character. This is proved by a series of examples of the synthesis of similar compounds, containing phenyl, p-tolyl and β-naphthyl radicals [12]. The double compound of phenyldiazonium chloride with antimony pentachloride ($C_6H_5N_2Cl \cdot SbCl_5$) was prepared, as will be reported later, by reacting the components in concentrated hydrochloric acid.

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* X denotes a halide, hydroxyl or aryl group.

EXPERIMENTAL

Reaction of phenylhydrazine, antimony trichloride and cupric chloride in equimolecular proportions, in a hydrochloric acid medium. a) Preparation of diphenylantimonic acid (I). In a wide-necked glass jar, antimony trichloride (57.1 g) and cupric chloride (42.5 g) were dissolved in concentrated hydrochloric acid (100 ml) and water (200 ml). Phenylhydrazine (27 g) was added dropwise with stirring to the solution obtained. After the addition of the phenylhydrazine, the reaction mixture was stirred for 5 hours with access to air. The pinkish precipitate formed was filtered off and washed with dilute hydrochloric acid (1 : 2) until the wash liquid became colorless*. The well pressed out precipitate was treated with 60-80 ml of acetone; the precipitate dissolved with the evolution of nitrogen and slight heat evolution. The acetone solution was filtered free from sediment and two volumes of ether and three volumes of water were added to the filtrate. The acid (I) isolated in this way was separated, washed with ether and dried. The yield was 6-7 g (15-18%), calculated on the antimony trichloride.

b) Preparation of diphenylstibine trichloride (II) from diphenylantimonic acid (I). 5 g of (I) was dissolved with heating in 200 ml of dilute hydrochloric acid (1 : 2). On cooling, the hydrochloric acid filtrate yielded (II) with m.p. 175°. The yield was 6 g (92%).

Found %: Sb 29.87. $C_{12}H_{10}Cl_3Sb \cdot H_2O$. Calculated %: Sb 30.4.

c) Preparation of diphenylchlorostibine from (II). 5 g of (II) was dissolved with heating in 125 ml of dilute hydrochloric acid (1 : 2), 15 ml of ethyl alcohol was added and the solution filtered**. 1-2 crystals of potassium iodide were added and a stream of sulfur dioxide passed for 40-60 minutes. After cooling and partial evaporation of the alcohol, crystals of diphenylchlorostibine separated***. The yield was 3 g (77%). The colorless plates (m.p. 69-70°) were readily soluble in alcohol, ether, and acetone.

Found %: Sb 39.00. $C_{12}H_{10}ClSb$. Calculated %: Sb 39.12.

d) Preparation of phenylantimonic acid (III). The filtrate and wash water, obtained after separating the precipitate during the preparation of diphenylantimonic acid, were stirred for a further 3-4 hours, filtered and an equal volume of concentrated hydrochloric acid, saturated in the cold with ammonium chloride, was added. The dark precipitate of the double salt $C_6H_5SbCl_4 \cdot NH_4Cl$ formed was filtered off, washed with hydrochloric acid, and stirred with 1 liter of water. After settling, the liquid was poured off and the precipitate separated and dried. The weight of (III) obtained was 13-14 g (20-22%).

e) Preparation of phenyldichlorostibine from (III). 10 g of (III) was treated in the cold with a mixture of 25 ml of hydrochloric acid and 35 ml of water. After careful stirring, the undissolved phenylantimonic acid (about 2 g) was separated off. 1-2 crystals of potassium iodide were added to the filtrate, which was saturated at 0° for 1.5-2 hours with sulfur dioxide. On cooling, colorless crystals separated. The yield of dry phenyldichlorostibine was 5 g (58%). The colorless needle-like crystals (m.p. 59-60°) were readily soluble in alcohol, acetone, and ether.

Found %: Sb 44.98. $C_6H_5Cl_2Sb$. Calculated %: Sb 45.15.

SUMMARY

We developed a new method of preparing antimonioaromatic compounds by reacting phenylhydrazine with antimony trichloride in a hydrochloric acid medium in the presence of aerobic oxygen. A mechanism for the reaction was proposed.

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*The filtrate and wash water was used for the preparation of phenylantimonic acid.

**When an oil separated, alcohol was added until the oil completely dissolved.

***After the separation of the diphenylchlorostibine, the mother liquor will yield a further small amount of product after distilling off the alcohol in vacuum.

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THE SYNTHESIS OF AROMATIC ANTIMONY COMPOUNDS

VII. THE PREPARATION OF p-FLUOROPHENYL DERIVATIVES OF ANTIMONY [1]

A. B. Bruker

In the previous report we described a new method of preparing phenyl- and diphenylantimonic acids, which consisted of reacting phenylhydrazine with antimony trichloride in a hydrochloric acid medium in the presence of cupric chloride and aerobic oxygen.

In this work we decided to check the possibility of preparing substituted phenyl- and diphenyl derivatives of antimony by this method. In connection with this, we studied the reaction of p-fluorophenylhydrazine with antimony trichloride in the presence of aerobic oxygen. The investigation of this reaction was also interesting as, if the results were positive, a series of new antimony compounds, containing fluorine in the benzene nucleus*, should be obtained.

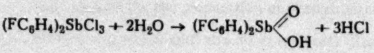
The reaction between p-fluorophenylhydrazine and antimony trichloride was carried out under conditions similar to those for the preparation of phenyl- and diphenylantimonic acids. Reaction of p-fluorophenylhydrazine with antimony trichloride in an aqueous hydrochloric acid medium resulted in the formation of a precipitate. Treatment of the precipitate with acetone and then water gave p,p'-difluorodiphenylantimonic acid. This acid was converted with concentrated hydrochloric acid into a trichloride, which, when reduced with SO_2, formed p,p'-difluorodiphenylchlorostibine. By hydrolyzing the latter we isolated the corresponding stibine oxide. The double compound p-fluorophenylstibine tetrachloride $FC_6H_4SbCl_4 \cdot NH_4Cl$ was precipitated by adding ammonium chloride to the mother liquor, after separation of the precipitate in the reaction of p-fluorophenylhydrazine with $SbCl_3$. Hydrolysis of this double compound gave p-fluorophenylantimonic acid. Reduction of the latter with sulfur dioxide in a hydrochloric acid medium gave p-fluoro-phenyldichlorostibine, which was hydrolyzed in the usual way to the corresponding oxide. The reactions of p-fluorophenylhydrazine with $SbCl_3$ may be expressed by the following equations

$$FC_6H_4NHNH_2 \cdot HCl + SbCl_3 + O_2 \xrightarrow{CuCl_2} FC_6H_4Cl \cdot SbCl_3 + 2H_2O \quad (1)$$

$$FC_6H_4NHNH_2 \cdot HCl + 2FC_6H_4N_2Cl \cdot SbCl_3 \rightarrow FC_6H_4N_2Cl + 2FC_6H_4 \cdot SbCl_3 + $$
$$+ 2N_2 + 4HCl \quad (2)$$

$$FC_6H_4N_2Cl + FC_6H_4SbCl_2 \rightarrow FC_6H_4N_2Cl \cdot FC_6H_4SbCl_2 \quad (3)$$

$$FC_6H_4SbCl_2 \cdot FC_6H_4N_2Cl \xrightarrow{(CH_3)_2CO} (FC_6H_4)_2SbCl_3 + N_2 \quad (4)$$



$$(FC_6H_4)_2SbCl_3 + 2H_2O \rightarrow (FC_6H_4)_2Sb(=O)OH + 3HCl \quad (5)$$

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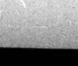
*Up to now there has only been reported the preparation of p-fluorophenylantimonic acid by the decomposition of the double compound  $N_2Cl \cdot SbCl_3$ [2].

The p-fluorophenylstibine dichloride obtained by reaction (2) was partially oxidized with cupric chloride and was thus converted into p-fluorophenylstibine tetrachloride, which was then isolated in the form of a double compound with ammonium chloride

$$FC_6H_4SbCl_2 + 2CuCl_2 \rightarrow FC_6H_4SbCl_4 + Cu_2Cl_2 \qquad (6)$$

$$FC_6H_4SbCl_4 + NH_4Cl \rightarrow FC_6H_4SbCl_4 \cdot NH_4Cl \qquad (7)$$

EXPERIMENTAL

a) Preparation of p,p'-difluorodiphenylstibinic acid (I). Antimony trichloride (28.5 g) and cupric chloride (21.2 g) were dissolved in dilute hydrochloric acid in a glass jar. In the presence of air, at room temperature and with stirring, p-fluorophenylhydrazine (16 g) was added dropwise. Stirring was continued for 3-4 hours until a test sample of the precipitate completely dissolved in acetone. The liquid was sucked off from the precipitate obtained, which was washed with dilute hydrochloric acid on the filter* and dissolved in acetone. Solution was accompanied by heating up and the vigorous evolution of nitrogen. The acetone solution was filtered and an equal volume of ether and three volumes of water added to the filtrate. The (I), which separated, was collected, washed with ether and dried. The yield was 3-3.5 g (14-16%). The white powder did not change up to 250°; it dissolved in glacial acetic acid on heating; it was practically insoluble in other organic solvents (benzene, ether, acetone).

Found %: Sb 35.24. $C_{12}H_9O_2F_2Sb$.

Calculated %: Sb 35.36.

b) Preparation of p,p'-difluorodiphenylstibine trichloride (II). 5 g of (I) was dissolved by heating in dilute hydrochloric acid (50 ml of conc. HCl and 50 ml of water), filtered and allowed to crystallize slowly. After several hours colorless crystals of (II) formed. The substance melted at 100°, then solidified and melted completely at 149-150°. It dissolved in alcohol, ether, acetone, and hot dilute hydrochloric acid.

Analysis of air-dried substance.

Found %: Cl 22.75; Sb 26.62. $C_{12}H_8F_2Cl_3Sb \cdot 2H_2O$.

Calculated %: Cl 23.43; Sb 26.84.

Analysis of substance heated at 100-105° to constant weight.

Found %: Cl 25.44; Sb 29.03. $C_{12}H_8F_2Cl_3Sb$.

Calculated %: Cl 25.44; Sb 29.12.

c) Preparation of p,p'-difluorodiphenylchlorostibine (III). 5 g of (II) was dissolved in 200 ml of dilute hydrochloric acid (1 : 1) by heating to 50°. 1-2 crystals of potassium iodide were added and the solution saturated with sulfur dioxide for 40-50 minutes. The chloride (III) precipitated as an oil, which crystallized on cooling. The white crystals (m.p. 55°) were soluble in the cold in alcohol, ether, and acetone.

Found %: Cl 10.35; Sb 34.49. $C_{12}H_8F_2ClSb$.

Calculated %: Cl 10.21; Sb 35.10.

d) Preparation of p,p'-difluorodiphenylstibine oxide. 5 g of (III) was dissolved in 25 ml of alcohol and poured with stirring into 150 ml of 5% ammonia. It was heated to 60-70° and allowed to cool slowly. Long colorless needles of the oxide with m.p. 85° separated. The oxide was readily soluble in alcohol and could be recrystallized from aqueous alcohol.

Found %: Sb 37.75. $C_{24}H_{16}OF_4Sb_2$.

Calculated %: Sb 38.12.

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*The filtrate was used for the preparation of p-fluorophenylstibinic acid.

e) Preparation of p-fluorophenylstibinic acid (IV). The filtrate, after the separation of the precipitate[*] was stirred for a further 3-4 hours until a bright green color appeared. It was filtered and an equal volume of concentrated hydrochloric acid, saturated with ammonium chloride in the cold, was added. The double salt of p-fluorophenylstibine tetrachloride and ammonium chloride precipitated. It was separated and washed with a saturated solution of ammonium chloride in concentrated hydrochloric acid. The double salt obtained was decomposed with water (0.5 liter). (IV) precipitated, was separated, washed with water, and dried. The yield was 5 g (15%). The white powder did not change on heating up to 230° and was insoluble in the bulk of organic solvents.

Found %: Sb 45.30. $C_6H_6O_3FSb$.

Calculated %: Sb 45.70.

f) Preparation of the double salt of ammonium chloride and p-fluorophenylstibine tetrachloride. 3 g of (IV) was dissolved with gentle heating in 30 ml of concentrated hydrochloric acid and a concentrated solution of ammonium chloride in hydrochloric acid was added to the solution obtained. Fine, slightly yellowish needles precipitated, which did not melt up to 230°. The double salt was soluble in alcohol, ether, acetone, and dilute hydrochloric acid.

Found %: Cl 42.76; Sb 29.42. $C_6H_8NCl_5FSb$.

Calculated %: Cl 43.03; Sb 29.57.

g) Preparation of p-fluorophenyldichlorostibine (V). 10 g of fluorophenylantimonic acid was dissolved in the cold in 25 ml of concentrated hydrochloric acid and 35 ml of water. The solution was filtered and saturated with sulfur dioxide at room temperature for 1-1.5 hours in the presence of a crystal of KI. We extracted (V) with ether, distilled off the ether and the clear oil was dried in a vacuum desiccator. The crystals obtained melted at 46-47° after drying on a porous plate and were soluble in alcohol, ether, acetone, and dilute hydrochloric acid.

Found %: Cl 24.52; Sb 41.74. $C_6H_4FCl_2Sb$.

Calculated %: Cl 24.65; Sb 42.36.

h) Preparation of p-fluorophenylstibine oxide. p-Fluorophenylstibine oxide was prepared by pouring an alcohol or an acetone solution of (V) into a 5% solution of ammonia. The precipitate was separated, washed with hot water, and dried. The white powder did not melt up to 280° and was insoluble in the bulk of organic solvents. On treatment with acetic acid it gave an acetate with m.p. 120-121°.

Found %: Sb 52.08. C_6H_4OFSb.

Calculated %: Sb 52.36.

SUMMARY

It was shown that the method we proposed for the preparation of phenyl and diphenylantimony compounds was applicable to the preparation of halogen derivatives, p-fluorophenyl derivatives, in particular. We prepared 7 compounds that are not described in the literature.

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[*] See experiment (a).

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REACTIONS OF FREE RADICALS IN SOLUTION

X. MECHANISM OF THE INHIBITING EFFECT OF POLYPHENOLS AND AROMATIC AMINES ON STYRENE POLYMERIZATION

B. A. Dolgoplosk and D. Sh. Korotkina

Polyphenols and aromatic amines are widely used for inhibiting radical processes, in particular that of polymerization [1].

The inhibiting effect of these compounds is usually associated with their capacity for destroying peroxides or hydroperoxides, which are sources of free radicals, or their capacity for reacting with free radicals so that hydrogen of the amine and phenol groups is abstracted to form inactive radicals, incapable of participating in the further development of the process[2].

The inaccuracy of these opinions was demonstrated by the results of this investigation, which showed that polyphenols and aromatic amines did not act as inhibitors in the thermal or initiated polymerization of styrene in the absence of oxygen.

Brietenbach [3] was the first to show that in the absence of oxygen, hydroquinone did not inhibit styrene polymerization and put forward the hypothesis that inhibition of polymerization is related to the oxidation of hydroquinone to quinone. In studying this phenomenon of thermal polymerization inhibition on the particular example given, Brietenbach made no generalizations from these observations.

EXPERIMENTAL AND DISCUSSION OF RESULTS

The effect of polyphenols and aromatic amines on the thermal polymerization of styrene. We studied the effect of hydroquinone and its ethers on the thermal polymerization of styrene at 100°, under the conditions described below (Fig. 1).

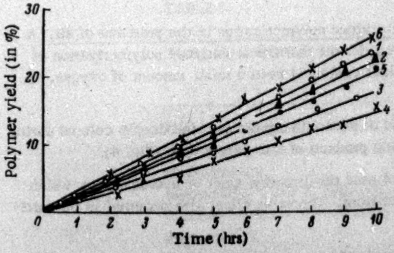


Fig. 1. Styrene polymerization kinetics in the presence of pyrocatechol, hydroquinone and its ethers, without oxygen. 1) without inhibitor; 2) pyrocatechol (0.09 mole %); 3) hydroquinone (0.09 mole %); 4) hydroquinone (0.47 mole %); 5) monomethyl ether of hydroquinone (0.09 mole %); 6) dimethyl ether of hydroquinone (0.45 mole %).

As can be seen, hydroquinone and its ethers and also pyrocatechol, do not produce an induction period in the absence of oxygen. The effect of the inhibitors given on the kinetics of styrene polymerization appeared only as a definite decrease of the rate of the process, which appeared greatest for hydroquinone and not at all for its ethers.

Various aromatic amines also have a similar effect on styrene polymerization in the absence of oxygen. Phenyl-β-naphthylamine, diphenylamine, and p-phenylenediamine were the examples of aromatic amines that we investigated (Fig. 2).

The data given show that phenyl-β-naphthylamine, diphenylamine, and p-phenylenediamine have no noticeable effect on the polymerization

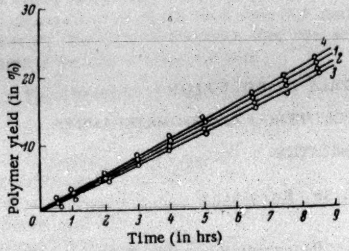


Fig. 2. Styrene polymerization kinetics in the presence of aromatic amines, without oxygen. 1) without inhibitors; 2) phenyl-β-naphthylamine (0.47 mole %); 3) p-phenylenediamine (0.1 mole %); 4) diphenylamine (0.1 mole %).

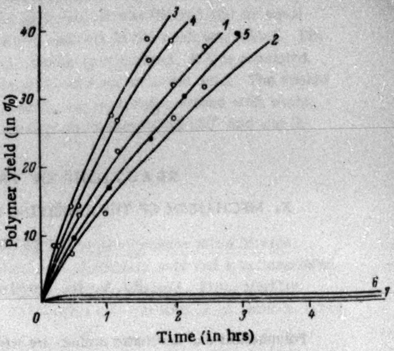


Fig. 3. The effect of hydroquinone and phenyl-β-naphthylamine on the initiated polymerization of styrene. In nitrogen: 1) isopropylbenzene hydroperoxide; 2) isopropylbenzene hydroperoxide + + hydroquinone; 3) benzoyl peroxide; 4) the same + hydroquinone; 5) isopropylbenzene hydroperoxide + phenyl-β-naphthylamine. In the presence of air: 6) isopropylbenzene hydroperoxide + + hydroquinone; 7) benzoyl peroxide + hydroquinone.

rate in the absence of oxygen.

The effect of hydroquinone and phenyl-β-naphthylamine on initiated polymerization of styrene. Styrene polymerization in the presence of benzoyl peroxide and isopropylbenzene hydroperoxide, with hydroquinone or phenyl-β-naphthylamine added, was carried out under the conditions described above, which exclude the possible entrance of oxygen.

All the substances were taken in 0.1 weight % amounts in relation to styrene (Fig. 3).

The rate of styrene polymerization under the effect of peroxides remained essentially the same in the presence of hydroquinone of phenyl-β-naphthylamine.

The effect of polyphenols and aromatic amines on styrene polymerization in the presence of air. A completely different picture was observed when the system for the thermal or initiated polymerization of styrene in the presence of polyphenols and aromatic amines contained even a small amount of oxygen. In this case a long induction period occurred.

The colorless or slightly colored solutions of amine or phenol in styrene became deeply colored during the induction period, indicating the formation of oxidation products of the quinoid type (Fig. 4).

An induction period was not observed only when we used the dimethyl ether of hydroquinone, which is incapable of oxidizing to quinone under the given conditions. The same effect also occurred in the initiated polymerization of styrene (Fig. 3, curves 6, 7).

The effect of polyphenols on styrene polymerization in the presence of peroxides and metal salts of variable valency. Prepared stable peroxides or molecular oxygen in a hydrocarbon medium and temperatures up to 100° were incapable of reacting at a noticeable rate with polyphenols and aromatic amines. However, this oxidation process occurred readily in the presence of oxygen and a monomer (styrene), which indicated that the primary reaction products of styrene and oxygen had a greater oxidizing potential than stable peroxides.

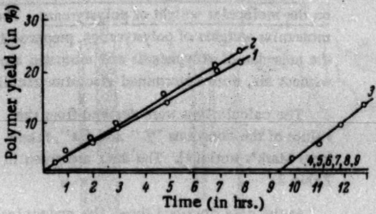


Fig. 4. The effect of polyphenols and aromatic amines on the thermal polymerization of styrene in the presence of air. 1) without inhibitor; 2) dimethyl ether of hydroquinone (0.45 mole %); 3) diphenylamine (0.1 mole %); 4) hydroquinone (0.47 mole %); 5) pyrocatechol (0.1 mole %); 6) monomethyl ether of hydroquinone (0.1 mole %); 7) phenyl-β-naphthylamine (0.47 mole %); 8) aminoazobenzene (0.1 mole %); 9) p-phenylenediamine (0.1 mole %).

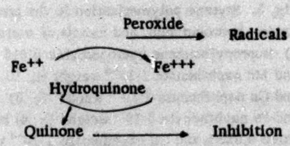
TABLE 1

Solvent	Hydroquinone concentration (in %)	Heating time (in hrs)	Hydroquinone found (as % of that taken)
Styrene	0.13	0	103
		6	46
Ethylbenzene	0.13	0	97
		4	103
		6	101

When heated to 100° in styrene in the presence of air hydroquinone was slowly converted to quinone. Under the same conditions the hydroquinone concentration in ethylbenzene practically remained unchanged (Table 1).

Higher metal salts (iron, copper, manganese, etc.) possess considerably greater oxidizing properties than peroxides and hydroperoxides. Thus, hydroquinone is oxidized by ferric salts even in the cold to form quinhydrone.

When the peroxides, hydroquinone and small quantities of naphthenates of the given metals are present together, a reverse cycle of conversions should occur which would lead to the full oxidation of hydroquinone to quinone.



In connection with quinone formation, styrene becomes colored.

As the experimental data in Fig. 5 show, in the absence of oxygen, polyphenols greatly inhibited polymerization in cases where the system contained even very small amounts of manganese, copper, or iron naphthenates.

The same inhibiting effect was observed when aromatic amine were used.

TABLE 2

Name of inhibitor	Inhibitor concentration (in mole %)	Polystyrene molecular weight
Without inhibitor	-	297000
Hydroquinone	0.09	237000
Hydroquinone	0.47	107600
Monomethyl ether of hydroquinone	0.47	260000
Dimethyl ether of hydroquinone	0.45	324000
Pyrocatechol	0.09	204000
Diphenylamine	0.1	307000
Phenyl-β-naphthylamine	0.1	313000
Phenyl-β-naphthylamine	0.47	314000

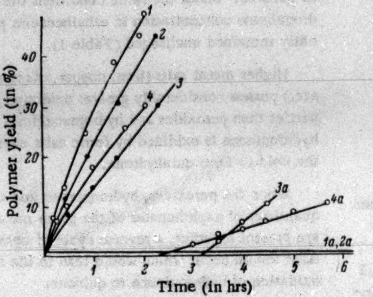


Fig. 5. Styrene polymerization in the presence of peroxides, hydroquinone, and metals of variable valency. 1) Isopropylbenzene hydroperoxide 0.015 weight % and Mn naphthenate $1 \cdot 10^{-4}$ weight %; 2) the same and Cu naphthenate $1 \cdot 10^{-4}$ weight %; 3) the same and Fe naphthenate $5 \cdot 10^{-3}$ weight %; 4) benzoyl peroxide 0.025% and Cu naphthenate $1 \cdot 10^{-4}$ weight %. 1a, 2a, 3a, 4a - the same as 1, 2, 3, 4 with 0.1 weight % of hydroquinone added.

The effect of polyphenols and aromatic amines on the molecular weight of polystyrenes. The molecular weights of polystyrenes, prepared in the presence of polyphenols and aromatic amines, without air, were determined viscosimetrically.

The calculations were derived from the values of the constants "K" and "a", taken from Mark's work [4]. The data are given in Table 2.

As the data obtained show, the molecular weight of polystyrenes decreased considerably in the presence of polyphenols (hydroquinone and pyrocatechol).

The change in molecular weight and decrease in polymerization rate in the presence of hydroquinone and pyrocatechol were due, apparently, to chain transferences, accompanied by the formation of radicals which were less active than the radicals of the growing chain.

The dimethyl ether of hydroquinone and aromatic amines did not affect the molecular weight of the polymers, which agrees fully with the absence of any effect of these compounds on polymerization kinetics in an oxygenless medium.

One may conclude from these data that the aromatic amines studied have a lower tendency to react with free hydrocarbon radicals than do polyphenols.

This work establishes that the inhibiting effect of polyphenols and aromatic amines is expressed only in the presence of oxygen or metal salts of variable valency in the system, which would result in their oxidation to form quinoidic compounds.

Procedure. In order to carry out the experiments under conditions excluding any possible entrance of oxygen into the system, we used an apparatus designed for simultaneous distillation and distribution of styrene into ampules that had been first sealed to a compressed air distributor (Fig. 6).

Before distillation the apparatus was freed from oxygen by pumping it out several times (5-7 times) with an oil pump to 1-2 mm and filling with purified nitrogen. The filling of the ampules with styrene was regulated by a movable lead tube inside the compressed air distributor using a magnet. The ampules were sealed off in a current of nitrogen.

The polymerization was carried out in an ultrathermostat at 100° ± 0.2°. The polymerization kinetics were determined dilatometrically. When the polystyrene yield reached 25-30% the process was stopped and the polystyrene content of the solution was determined gravimetrically.

Two methods were used for the quantitative determination of hydroquinone: a) hydroquinone oxidation to quinone in an acidic medium with a 0.1 N solution of potassium dichromate in the presence of diphenylamine as indicator [5]; b) hydroquinone oxidation to quinone with excess 0.05 N iodine solution in an acetic acid medium. The excess iodine was titrated with hyposulfite [6].

Quinone was determined by reduction with potassium iodide in an acidic medium followed by titration of the iodine evolved with a 0.1 N hyposulfite solution.

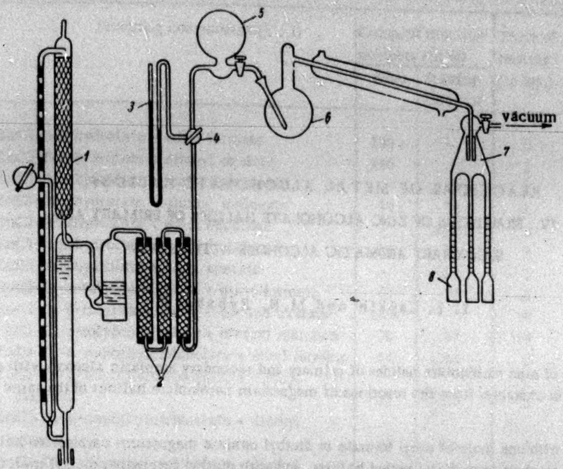


Fig. 6. Diagram of the apparatus for loading the monomer into the ampules. 1) Column for purifying nitrogen; 2) drying system; 3) manometer; 4) three-way tap; 5) fore reservoir; 6) distillation flask; 7) "compressed air distributor" with movable lead tube; 8) reaction ampules.

SUMMARY

1. It was established that aromatic amines and polyphenols were not inhibitors of the thermal polymerization of styrene.

2. It was established that aromatic amines and polyphenols acted as polymerization inhibitors only in systems containing oxygen or metal salts of variable valency, capable of oxidizing phenols and amines to the corresponding quinones.

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REACTIONS OF METAL ALCOHOLATE HALIDES

IV. REACTIONS OF ZINC ALCOHOLATE HALIDES OF PRIMARY AND SECONDARY AROMATIC ALCOHOLS WITH ESTERS

I. I. Lapkin and M.N. Rybakova

The reactions of zinc carbinolate halides of primary and secondary aromatic alcohols with esters are somewhat different in character from the reactions of magnesium carbinolate halides of the same alcohols [1-3].

When treated with one mole of ethyl formate or diethyl oxalate magnesium carbinolate halides of secondary aromatic alcohols form diarylmethyl halides, and with diethyl succinate, diethyl malonate and diethyl sulfate form ethers, while the zinc carbinolate halides of the same alcohols react with all the above esters (with the exception of diethyl succinate, which does not react with the given carbinolates) to form only ethers.

This is explained by the retardation of diarylmethyl halide formation in treating zinc carbinolate halides with esters, and as a result the following reaction occurs

$$R_2CHCl + R_2CHOZnCl \rightarrow R_2CH - O - CHR_2 + ZnCl_2.$$

The experimental results are given in the table.

The data in the table show, firstly, that a rise in the electro-negativity of the aryl radicals and, consequently, in the lability of the hydroxyl group, increased the ether yield; secondly, a decrease in the dissociation constant of the acids from which the esters were formed resulted in a lowering of the product yield. Zinc di-α-naphthylcarbinolate chloride appeared to be an exception due to its low solubility in ethyl ether. Zinc carbinolate chlorides of secondary aromatic alcohols, the same as magnesium carbinolate halides, do not react with ethyl acetate and ethyl benzoate in equimolecular ratios.

In contrast to the magnesium carbinolate halides, the zinc carbinolate chlorides of primary aromatic alcohols did not react with the esters given in equimolecular amounts.

EXPERIMENTAL

The general conditions for the reaction between zinc carbinolate chlorides and esters were as follows.

Into a flask was placed finely powdered anhydrous zinc chloride, which was covered with a layer of anhydrous ethyl ether (3 volumes), then an equimolecular amount of ethylmagnesium bromide in ether solution was added to the same flask and the mixture heated for 1 hour. The carbinol, dissolved in an equal amount of anhydrous ether, was added to the ethylzinc chloride obtained in this way. If the carbinol was difficultly soluble in ether, as for example di-α-naphthylcarbinol, 1 volume of toluene was added to it to increase the solubility. The reaction mixture was again heated for 30 minutes and then the ester, in an amount equimolecular with the carbinol, was introduced into the flask via a dropping funnel. To complete the reaction between the zinc carbinolate chloride and the ester, the contents of the flask were heated on a water bath for a definite time (see table). After this, the cooled reaction mixture was decomposed with

Experiment No.	Reacting components (1 : 1)	Comp. of reaction products (in %)		Time of heating (in hrs.)	Melting point according to	
		Ether	Starting carbinol		Experimental data	Literature data
1	ZnCl-Benzhydrolate + ethyl formate	100	-	3	110°	109-110° [4]
2	ZnCl-Benzhydrolate + diethyl oxalate	100	-	3	110	109-110° [4]
3	ZnCl-Benzhydrolate + diethyl succinate	-	100	3	68	68 [5]
4	ZnCl-Benzhydrolate + diethyl malonate	30	70	3	-	-
5	ZnCl-Benzhydrolate + ethyl benzoate	-	100	3	68	68 [5]
6	ZnCl-Benzhydrolate + diethyl sulfate	30	70	3	-	-
7	ZnCl-Benzhydrolate + ethyl acetate	-	100	3	68	68 [5]
8	ZnCl-Di-p-tolylcarbinolate + ethyl formate	67	33	3	-	-
9	ZnCl-Di-p-tolylcarbinolate + diethyl oxalate	100	-	6	186	Not described*
10	ZnCl-Di-p-tolylcarbinolate + diethyl malonate	33	67	6	-	-
11	ZnCl-Di-α-naphthylcarbinolate + ethyl formate	54	46	3	-	-
12	ZnCl-Di-α-naphthylcarbinolate + diethyl oxalate	35	65	3	-	-
13	ZnCl-Di-α-naphthylcarbinolate + diethyl oxalate	66	34	6	-	-
14	ZnCl-Di-α-naphthylcarbinolate + diethyl oxalate	100	-	12	247	246.5 [6]

water and 10% acetic acid. The ether layer was separated from the water, washed with 10% soda solution, then water and dried with calcium chloride. The ether was distilled off and the residue analyzed. First the unreacted carbinol was determined by analysis for the hydroxyl group and then the carbinol was separated from the ether formed by vacuum distillation, and both substances were purified by recrystallization. Only di-α-naphthylmethyl ether separated during the washing of the ether layer (due to its low solubility in wet ethyl ether).

SUMMARY

1. We studied the reactions of zinc carbinolate chlorides of secondary aromatic alcohols with esters. It was established that zinc carbinolate halides of these alcohols were completely converted into the corresponding ethers by reacting them with an equimolecular amount of ethyl formate of diethyl oxalate. The carbinolates mentioned were also converted into these substances by reacting them with diethyl malonate and diethyl sulfate but in lower yields. This method of converting secondary aromatic alcohols into ethers may be recommended for preparative purposes.

2. Zinc carbinolate chlorides of primary aromatic alcohols did not react with equimolecular amounts of esters.

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*Found %: C 88.42; H 7.39. $C_{30}H_{30}O$. Calculated %: C 88.63; H 7.44

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Molotov State University

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*Original Russian pagination. See C. B. translation.

SYNTHESIS OF β-DIIODOTYROSINE

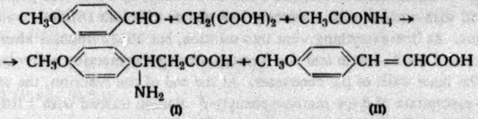
V. M. Rodionov*, N. N. Suvorov, V. G. Avramenko and L. M. Morozovskaya

The pharmacological connection between β-amino acids and the isomeric α-amino acids, which are of great physiological value, is still an unsolved problem. Nonetheless, it is possible that in a series of cases β-amino acids could be substitutes or antimetabolites of the corresponding compounds of the α-series, which could be of definite theoretical and practical interest.

For this purpose, in 1952 we synthesized β-(4-hydroxy-3,5-diiodophenyl)-β-alanine, which is the β-analog of the physiologically active α-aminoacid - 3,5-diiodotyrosine. As the latter possesses a definite antithyroidin activity and, as a result, is used in treating thyrotoxicoses [1], it was simple to detect the physiological activity of β-diiodotyrosine.

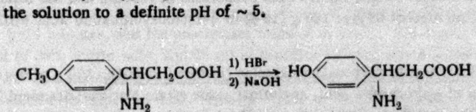
We developed the following scheme for synthesizing the latter.

Reaction of anisaldehyde with malonic acid and ammonium acetate, by V. M. Rodionov's reaction, gave a mixture of β-(4-methoxyphenyl)-β-alanine (I) and 4-methoxycinnamic acid (II), which was readily separated as the β-amino acid was insoluble in hot butyl alcohol and precipitated in a pure state.



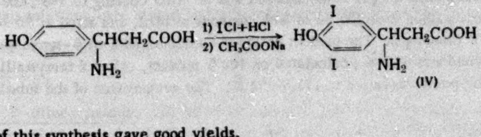
(I) (II)

Demethylation of the β-amino acid (I) by boiling with a 7-fold amount of 40-48 % hydrobromic acid lead to the formation of β-(4-hydroxyphenyl)-β-alanine (β-tyrosine) (III), which was isolated from the hydrobromide by bringing the solution to a definite pH of ~ 5.



(III)

The β-tyrosine may be iodinated either with an aqueous solution of iodine and potassium iodide in an ammonia medium, or, better, with iodine chloride in hydrochloric acid.



(IV)

All the stages of this synthesis gave good yields.

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* Deceased.

β-(4-hydroxy-3,5-diiodophenyl)-β-alanine (β-diiodotyrosine) (IV), is a colorless or slightly yellowish crystalline substance, very difficultly soluble in water, practically insoluble in organic solvents, and readily soluble in aqueous solutions of hydrochloric acid, caustic alkalis, and ammonia. The melting point is not characteristic: due to strong decomposition of the substance at high temperatures, the melting point lies in the range 177-185° on the condition that the capillary is inserted less than 10° before melting starts and the rate of heating is 3° per minute (β-diiodotyrosine should decompose within the limits of 1°). Usually the melting point of β-diiodotyrosine is 178-179°.

Being an amino acid, β-diiodotyrosine has amphoteric properties. However, the basicity of the amino group is greatly lowered by the presence of a phenolic hydroxyl adjacent to the iodine atoms. Due to this β-diiodotyrosine hydrochloride is almost instantaneously hydrolyzed when dissolved in water.

The disodium salt (at the carboxyl and phenolic hydroxyl groups), which is readily soluble in water, may be prepared with sodium hydroxide. In the case of a weaker base, such as ammonia, a salt is formed only at the carboxyl group.

To characterize β-diiodotyrosine we prepared its N-benzoyl derivative, N-acetyl derivative, and the ethyl ester of N-acetyl-β-(4-hydroxy-3,5-diiodophenyl)-β-alanine.

In 1952, tests performed by A. E. Rabkina in the laboratories of Prof. E. I. Tarakanov* of the All-Soviet Institute for Research on Endocrinology showed the high antithyroidin activity of β-diiodotyrosine. The latter, under the name of "betasine," has been authorized for wide medical application in the treatment of thyrotoxicoses.

Thus, at least on this example the similarity in the physiological activity of amino acids of the α- and β-series with analogous structures has been shown.

EXPERIMENTAL

Preparation of β-(4-methoxyphenyl)-β-alanine (I). 500 g of freshly distilled anisaldehyde, 390 g of malonic acid, 760 g of ammonium acetate, and 2 liters of n-butyl alcohol were placed in a 10 liter round-bottomed flask, fitted with a stirrer with a mercury seal and an efficient Dimroth condenser. The mixture was boiled for 3 hours. At first everything went into solution, but 30-40 minutes after boiling began, a voluminous precipitate of the β-amino acid was formed. During the reaction a precipitate of ammonium acetate formed on the inner walls of the condenser. At the end of the reaction, the reaction mixture was filtered hot and the precipitate of β-(4-methoxyphenyl)-β-alanine washed with 1 liter of hot n-butyl alcohol, then 200-300 ml of ethyl alcohol, and dried at 50-60°. The yield was 386 g (54%). The m. p. was 222-223° (decomp.). This β-aminoacid was quite suitable for further reactions.

The combined alcohol mother liquors were evaporated in vaccum and the residue ground with water and recrystallized from alcohol to give 126 g (19%) of 4-methoxycinnamic acid with m.p. 170° (clear fusion at 185°).

Preparation of β-(4-hydroxyphenyl)-β-alanine (β-tyrosine) (III). 100 g of β-(4-methoxyphenyl)-β-alanine and 700 ml of hydrobromic acid, analytical grade (State National Standard 2062-48), were placed in a 1 liter round-bottomed flask, fitted with ground joint reflux condenser. The mixture was boiled for 4 hours. The pale purple precipitate, formed at first, dissolved on heating and the solution became red. At the end of the reaction, the hot solution was treated with 5 g of active charcoal, stirred and filtered, and the filtrate evaporated in vacuum. We obtained 150 g of crude β-tyrosine hydrobromide. It was dissolved in 150 ml of water and 60 ml of 40% aqueous sodium hydroxide added at 50-60° to bring it to pH 8 and then acetic acid was added until the pH of the solution was 5. After cooling to 7-8°, the precipitate of β-tyrosine was separated, washed with 250 ml of 50% aqueous alcohol, and dried at 50-60°. We obtained 64.8 g with m.p. 170-171° (decomp.). The product obtained contained 96% of β-tyrosine and was suitable for iodination. The yield was 67.5 %, calculated on 100% product. After 2 recrystallizations from 50% aqueous alcohol the melting point was raised to 173.5-174.5°. The composition of the substance corresponded to β-(4-hydroxyphenyl)-β-alanine, for which, however, Posner [2] reported m.p. 198°.

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*We would like to take this opportunity to thank them for carrying out these tests.

Found %: C 59.40, 59.51; H 6.26, 6.19; N 7.71, 7.79. $C_9H_{11}O_3N$.

Calculated %: C 59.66; H 6.07; N 7.73.

For characterization of the β-tyrosine obtained, its O,N-dibenzoyl derivative was prepared by benzoylation using the Schotten-Baumann method. The m.p. was 194-194.5° (decom.) from 20% aqueous alcohol.

Found %: N 3.94, 4.11. $C_{23}H_{19}O_5N$.

Calculated %: N 3.60.

Preparation of β-(4-hydroxy-3,5-diiodophenyl)-β-alanine (β-diiodotyrosine) (IV). a) Iodination with iodine chloride. The iodine chloride was prepared by passing 35.5 g of chlorine into 127 g of iodine. We had to remember that even a slight excess of chlorine would give ICl_3, which has an adverse effect on the iodination. For storage, 5% by weight of concentrated hydrochloric acid was added to it.

30 g of β-tyrosine, 18 ml of concentrated hydrochloric acid, and 150 ml of water were placed in a three-necked, liter flask, fitted with a stirrer, a thermometer, and a dropping funnel. The solution obtained was heated to 60° and at this temperature a solution of 56.5 g of iodine chloride in 38 ml of 20% hydrochloric acid was added over a period of 20-30 minutes. At the end of the addition, the mixture was stirred at 60° for 2 hours, cooled to 8-10°, and the precipitate of β-diiodotyrosine hydrochloride (85 g) filtered off. Then it was dissolved in 800 ml of water at 50-60°, treated with 4-5 g of active charcoal and filtered. 20--25% aqueous sodium acetate was added to the solution obtained until it was no longer acid to congo. The precipitate of β-diiodotyrosine was filtered off, washed, and reprecipitated. For this purpose it was dissolved in a mixture of 1200 ml of water and 30 ml of concentrated hydrochloric acid, the solution obtained heated to 70°, and 20-25% sodium acetate solution added dropwise at this temperature until the solution was no longer acid to congo. The precipitate of β-diiodotyrosine was filtered off, washed and reprecipitated. For this purpose it was dissolved in a mixture of 1200 ml of water and 30 ml of concentrated hydrochloric acid, the solution obtained heated to 70° and 20-25% sodium acetate solution added dropwise at this temperature until the solution was no longer acid to congo. The reaction mixture was cooled to 20-30° and the precipitate filtered off, washed with water, and dried at a temperature no higher than 50°. We obtained 60.7 g (88.2%) of β-diiodotyrosine with m.p. 178-179° (decomp.).

Found %: I 58.41, 58.10; N 3.26, 3.14. $C_9H_9O_3NI_2$.

Calculated %: I 58.62; N 3.23.

b) Iodination with iodine in an ammonia medium. 460 ml of an aqueous solution of 117 g of iodine and 100 g of potassium iodide was added dropwise over a period of 1-1.5 hours to a solution of 42 g of β--tyrosine in 300 ml of 12% aqueous ammonia, which was stirred vigorously at a temperature of 3-5°. Then the solution was stirred for 1 hour at the same temperature, 65 ml of saturated sodium bisulfite solution added, the solution stirred for 5-10 minutes, and the precipitate allowed to settle. The liquid was poured off and 200 ml of water, 65 ml of 98% acetic acid, and 25 ml of bisulfite solution added to the precipitate. The mixture was heated to 60° and stirred for 30 minutes, cooled, and the β-diiodotyrosine sucked off and washed. We obtained 89 g of product with m.p. 146-148°. This β-diiodotyrosine was purified by reprecipitation, as described above. The yield was 79 g (78.6%). The m.p. was 178-179° (decomp.).

β-Diiodotyrosine hydrochloride. 17 g of β-diiodotyrosine was dissolved in 170 ml of 2% hydrochloric acid. 50 ml of concentrated hydrochloric acid was added to the solution, which was cooled, and the precipitated β-diiodotyrosine hydrochloride filtered off and washed with alcohol and ether. The weight was 15.2 g. The colorless crystalline material did not have a definite melting point. It was quite difficultly soluble in water; aqueous solutions were almost immediately hydrolyzed to precipitate β-diiodotyrosine.

Found %: Cl' 7.29, 7.38. $C_9H_9O_3NI_2 \cdot HCl$.

Calculated %: Cl' 7.55.

Disodium salt of β-diiodotyrosine. 150 ml of 10% aqueous sodium hydroxide was added with vigorous stirring to a suspension of 50 g of β-diiodotyrosine in 600 ml of alcohol. The solution obtained was filtered. On standing, a heavy crystalline precipitate began to come out. It was filtered off, washed with alcohol, and dried to constant weight in vacuum at 45-50°. The yield was 37 g. The yellowish crystalline material was readily soluble in distilled water. Aqueous solutions had a clearly expressed alkaline reaction:

the pH of a 1% solution of the disodium salt was 10.5.

Found %: Na 9.05; I 49.48; H_2O (by Fischer's method) 7.66. $C_9H_7O_3NI_2Na_2 \cdot 2H_2O$.

Calculated %: Na 8.96; I 48.61; H_2O 7.02.

Ammonium salt of β-diiodotyrosine. 4 g of β-diiodotyrosine was dissolved with heating in 20 ml of 25% aqueous ammonia. On cooling, the ammonium salt of β-diiodotyrosine crystallized out from the solution. The colorless crystalline material with m.p. 151-152° (decomp.) was quite difficultly soluble in cold water.

Found %: N 6.19, 6.27; I 53.59; H_2O (by Fischer's method) 3.14. $C_9H_{12}O_3N_2I_2 \cdot H_2O$.

Calculated %: N 5.98; I 54.23; H_2O 3.81.

N-Benzoyl-β-diiodotyrosine. 1 g of β-diiodotyrosine was dissolved in 8 ml of 13% aqueous sodium hydroxide. 0.6 ml (0.72 g) of benzoyl chloride was added dropwise with very vigorous stirring to the solution obtained, keeping the reaction mixture temperature at 5-8°. Then the latter was stirred for 1 hour at room temperature, filtered, and the impurities extracted with ether. The alkaline solution was acidified to congo with hydrochloric acid (1 : 3). The precipitate was separated, washed with alcohol, and dried. After two crystallizations from aqueous alcohol, we obtained 0.9 g of the N-benzoyl derivative with m.p. 206.5-207° (decomp.).

Found %: C 35.97, 35.89; H 2.61, 2.66; N 3.12, 3.25. $C_{16}H_{13}O_4NI_2$.

Calculated %: C 35.76; H 2.44; N 2.61.

N-Acetyl-β-diiodotyrosine. 5.2 ml (5.6 g)of acetic anhydride was added dropwise with very vigorous stirring to a suspension of 4 g of β-diiodotyrosine in 200 ml of saturated potassium bicarbonate solution at room temperature. The reaction was then worked up as described above. After recrystallization from a mixture of methyl ethyl ketone and heptane, we obtained 2.5 g of the N-acetyl derivative with m.p. 219-219.5° (decomp.).

Found %: C 28.13, 28.02; H 2.55, 2.63; N 2.74, 2.81. $C_{11}H_{11}O_4NI_2$.

Calculated %: C 27.79; H 2.34; N 2.94.

Ethyl ester of N-acetyl-β-diiodotyrosine. 2.2 g of N-acetyl-β-diiodotyrosine was heated at 40° with 1.1 ml (1.9 g) of thionyl chloride, excess of the latter distilled off in vacuum, and the residual oil mixed with 10 ml of anhydrous alcohol. After standing at room temperature for 1 hour, the reaction mixture was boiled for 30 minues, cooled, and diluted with water. The tarry material, which first precipitated, crystallized on standing. The m.p. was 125-126° (from a toluene-heptane mixture).

Found %: C 31.00, 31.11; H 2.88, 2.95; N 2.80, 2.67. $C_{13}H_{15}O_4NI_2$.

Calculated %: C 31.04; H 2.99; N 2.78.

SUMMARY

We synthesized a new antithyroidin preparation β-diiodotyrosine ("betasine").

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* In Russian.

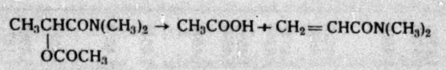
SYNTHESIS OF N-SUBSTITUTED METHACRYLAMIDES

III. N-ALKYLACRYL- AND N-ALKYLMETHACRYLAMIDES

M. M. Koton, T. A. Sokolova, M. N. Savitskaya and T. M. Kiseleva

N-Alkylacryl- and -methacrylamides are obtained from saturated compounds when the double bond is formed by eliminating molecules of acetic acid, hydrogen chloride, or another compound, or from the derivatives of these unsaturated acids.

The pyrolysis of N-alkylamides of α-acetoxypropionic or isobutyric acids at a temperature of 500--560° belongs to the first group of methods [1,2].



$$CH_3\underset{\substack{|\\ OCOCH_3}}{C}HCON(CH_3)_2 \rightarrow CH_3COOH + CH_2{=}CHCON(CH_3)_2$$

Substituted amides are obtained in good yields by pyrolysis, but they are difficult to separate from acetic acid, with which they form constant boiling mixtures. There are indications that in the exchange reaction of acrylates with alkylamines, the simultaneous addition of amine at the double bond also occurs [1]. The compounds thus obtained decompose at high temperature to form acrylamides; it was noted that the stability of such compounds decreased with the elongation of the alkyl chain at the nitrogen [3]. It was also established that alkylmethacrylamides were most readily prepared by this method. We may assume that the stability of these compounds is related to the ease with which they are formed. Methacrylates add alkylamines less readily at the double bond than do acrylates [4].

According to patent data [5], N-alkyl-β-alkylaminopropionamides or the corresponding isobutyramides give N-alkylamides of acrylic or methacrylic acids when heated with acids.

N-Alkylacrylamides are also obtained on treating N-alkylchloropropionamides with alkali [6]. Acrylamides are obtained on treating 1 mole of propionic acid β-lactone with 2 moles of alkylamine [7].

Using the second method, N-alkylamides of acrylic and methacrylic acids are synthesized from the derivatives of these unsaturated acids. Methyl-, dimethyl- and ethylacrylamides are obtained on passing amines of the aliphatic series through a benzene solution of acrylyl chloride [1,8]. Methylmethacrylamide is formed by mixing benzene solutions of the amine and methacrylyl chloride [9], or by reacting an aqueous solution of methylamine hydrochloride with a benzene solution of methacrylyl chloride with the gradual addition of an aqueous solution of sodium hydroxide. N-Teriary butylmethacrylamide is obtained on passing isobutylene into a solution of methcrylonitrile in a mixture of acetic and sulfuric acids [9]. For identification it is also prepared from the amine hydrochloride and methacrylyl chloride.

Experimental checking has shown that the most suitable laboratory method, which gives alkylmethacrylamides in good yields, is the reaction of acrylyl and methacrylyl chlorides with solutions of the amine. Due to the strong degree of basicity of the alkylamines (K_{bas} of the order of 10^{-4}) the acylation reaction proceeded extremely vigorously with a large heat effect and therefore cooling was necessary. In order to bind the hydrogen chloride evolved during the reaction, 2 moles of amine had to be used per mole of acid chloride. Besides that, the degree of water solubility of the N-alkylamide formed had to be considered in selecting the solvent medium. Thus, for example, methyl-, ethyl- and piperidyl-substituted amides of acrylic and methacrylic acids could not be prepared in good yields in an aqueous medium due to the very

Name of monomer	Boiling point (pressure mm)	Yield (in %)	Purity of bromination	Nitrogen content (%)		d_4^{20}	n_D^{20}	MR_D		Water solubility	Literature reference
				Found	Calc.			Found	Calc.		
Methylacrylamide	86—87° (3) 84 (3)	71.4	—	16.50	16.47	0.9872 0.9963	1.4722 1.4700	24.10	23.79	Dissolves	[7, 8, 10—12]
Ethylacrylamide	99—100 (5) 127—130 (25)	80	—	—	—	0.948 0.978 при 0°	1.4668	28.9	28.4	Dissolves	[8, 11]
Diethylacrylamide	85—86 (10) 95 (19)	76.9	99.3	—	—	0.925 0.9256	1.4670 1.4676	38.3	37.7	Dissolves	[3, 7, 10—12]
Methylmethacrylamide	86 (4) 88 (5.5)	78	99.9	14.42	14.14	0.9730 0.9701	1.4741 1.4740	28.57	28.44	Dissolves	[9—12]
Dimethylmethacrylamide	67 (10) 66—67 (10)	66	99.94	12.85	12.39	0.9289 0.9272	1.4599 1.4594	33.30	33.05	Dissolves	[10]
Ethylmethacrylamide	88—89 (5) 87 (0.8)	80.2	100	—	—	0.936	1.4672	33.51	33.05	Dissolves	[11]
Diethylmethacrylamide	74—75 (8)	91.1	100	—	—	0.904	1.4547	42.29	42.29	Dissolves	
n-Butylmethacrylamide	113 (6) 118 (10)	55	—	—	—	0.9198	1.4667	42.50	42.30	Does not dissolve	[12]
n-Octylmethacrylamide *	141 (2)	62	—	6.96	7.11	0.8961	1.4681	61.14	60.76	Does not dissolve	
Piperidylmethacrylamide	100—100.5(5) 117 (16)	29	—	9.68	9.15	0.9870 0.9826 (23.5°)	1.4907 1.187 (23.5°)	44.87 44.78	45.05	Does not dissolve	[13]

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* Found %: C 72.99, 72.95; H 11.73, 11.90. $C_{12}H_{23}ON$. Calculated %: C 73.10; H 11.68.

high water solubility of these amides which made it impossible to extract them sufficiently well from aqueous solutions, even by several extractions with benzene. These N-substituted amides were prepared in good yields when the reaction was carried out in a benzene solution. The amine hydrochloride thus formed precipitated out of the benzene solution and could be readily isolated by filtration followed by washing with benzene.

The higher N-alkyl-substituted amides of methacrylic acid are, on the contrary, insoluble in water and were prepared in good yields by reacting the acid chloride with the alkylamine in an aqueous medium. In this case the alkylamine hydrochloride formed passed into the aqueous layer, which was readily separated from the layer formed by the reaction product. Thus we prepared n-butyl and n-octylmethacrylamides.

In the table the properties of the amides synthesized are compared with those of compounds described in the literature, and the values of molecular refraction, which agree well with the calculated ones, are also given there.

We were the first to synthesize n-octylmethacrylamide. We also characterized diethylmethacrylamide which had been prepared earlier [12], but whose properties had not been described.

EXPERIMENTAL

Acrylic acid was prepared by transesterification with formic acid [14].

Acrylyl chloride was prepared by heating acrylic acid with benzoyl chloride to give 75% yield [15].

Methacrylyl chloride was prepared similarly to acrylyl chloride [15] or by heating with thionyl chloride and subsequently distilling at normal pressure (b.p. 98-100°).

Preparation of ethylacrylamide. A solution of 38.9 g of ethylamine in 120 ml of benzene was introduced into a two-necked, round-bottomed flask, fitted with a reflux condenser, a dropping funnel, and a mechanical stirrer. The flask was cooled externally with ice. Over a period of two hours a solution of 39 g of the acid chloride in benzene was added dropwise from the dropping funnel with stirring. The reaction occurred with the evolution of heat. The ethylamine hydrochloride formed precipitated. After the addition of the acid chloride, the reaction mixture was left at room temperature for 2 hours. The ethylamine hydrochloride was filtered off on a Buchner funnel, pressed on it, and washed several times with benzene. The combined filtrates were dried with anhydrous magnesium sulfate. After distilling off the benzene, the ethylacrylamide left was fractionated under reduced pressure.

By similar methods we prepared diethylacrylamide, ethylmethacrylamide, and diethylmethacrylamide. The characteristics of the products and the yields are given in the table.

Preparation of methylacrylamide. Gaseous methylamine was passed into a solution of acrylyl chloride in benzene in a two-necked, round-bottomed flask, externally cooled in ice, until a test from the reaction mixture gave a faint blue color with neutral litmus paper. The precipitated methylamine hydrochloride was filtered off and washed with benzene. After distilling off the benzene from the filtrate, the residue was distilled in vacuum. The properties of the product are given in the table.

Preparation of methylmethacrylamide. A benzene solution of methylamine was prepared by passing gaseous methylamine from a tank into benzene in a measuring cylinder, cooled in ice.

A solution of 100 g of methacrylyl chloride in 400 ml of benzene was placed in a two-necked, round-bottomed flask, fitted with a stirrer and a dropping funnel, and cooled externally in a cooling mixture. 800--900 ml of a previously prepared benzene solution of methylamine was gradually added to the solution. The reaction proceeded with the evolution of heat. The methylamine hydrochloride formed precipitated. The addition of the benzene solution was stopped when a test of the reaction mixture gave a faint lilac color on bromocresol purple paper. The methylamine hydrochloride was filtered off on a Buchner funnel and washed with benzene. A small amount of cuprous chloride was added to the benzene filtrate as an inhibitor and the benzene was distilled off. The residue was distilled in vacuum.

Dimethylmethacrylamide was prepared similarly.

Preparation of n-butylmethacrylamide. 25 g of butylamine, dissolved in 300 ml of water, was placed in a flask, fitted with a stirrer and a dropping funnel, and cooled externally with ice. 17.7 g of methacrylyl chloride was gradually added to the cooled solution from the dropping funnel. The n-butylmethacrylamide obtained gave an emulsion, which separated as a layer after standing in a separating funnel. The aqueous layer was twice extracted with ether. The ether extracts were combined with the main product, washed with water, and dried with anhydrous copper sulfate. After evaporating off the ether, the residue was distilled in vacuum over cuprous chloride, as a polymerization inhibitor.

n-Octylmethacrylamide was prepared similarly.

SUMMARY

1. N-Alkylacrylamides (methyl-, ethyl-, dimethyl- and diethyl-) and N-alkylmethacrylamides (methyl-, ethyl-, dimethyl-, diethyl- and piperidyl-) were prepared in good yields by acylations with acrylyl and methacrylyl chlorides, respectively, in a benzene medium.

2. n-Butyl and n-octylmethacrylamides may be prepared by acylations with methacrylyl chloride in an aqueous medium.

3. n-Octylmethacrylamide was prepared and characterized for the first time. Diethylmethacrylamide, whose properties have not been previously described in the literature, was synthesized and characterized.

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THE REACTION OF FLUORINATED CARBOXYLIC AND THIOCARBOXYLIC ACID HALIDES WITH SODIUM AZIDE

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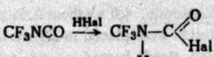
As was shown previously by Huckel, fluorinated carboxylic acid halides undergo a Curtius rearrangement to form fluorinated isocyanates when treated with sodium azide. By this method they obtained trifluoromethyl-, difluoromethyl- and monofluoromethyl isocyanates from trifluor-, difluor- and monofluor-acetyl chlorides, respectively, and sodium azide [1].

However, in Huckel's report there was no description of the experimental conditions, which made repetition difficult in the following report [2], and Huckel's reaction was reproduced only in patent work [3] for isocyanates of the general formula $CF_3(CF_2)_nNCO$, where n = 1 − 10. As far as fluorinated thiocarboxylic acid halides are concerned, they were unknown up to now.

The purpose of this work was to compare the course of the reactions of fluorinated carboxylic and thiocarboxylic acid halides with sodium azide.

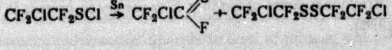
The very first experiments on the reaction of sodium azide with trifluoracetyl bromide and then with difluoracetyl bromide showed that the reaction gave fluoroalkyl isocyanates only in cases where the sodium azide had been previously activated. The sodium azide was activated with hydrazine hydrate [4].

It was established that the trifluoromethyl isocyanate thus obtained readily added one molecule of hydrogen halide to form N-trifluoromethylcarbanyl halides, which up to now have been unknown.



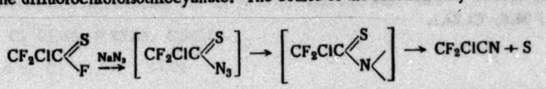
$$CF_3NCO \xrightarrow{HHal} CF_3N(H){-}C(=O)Hal$$

As an example of fluorinated thiocarboxylic acid halides we used difluorochlorothioacetyl fluoride, which we prepared by reacting 2-chlorotetrafluoroethylsulfenyl chloride with tin

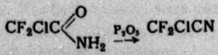


$$CF_2ClCF_2SCl \xrightarrow{Sn} CF_2ClC(=S)F + CF_2ClCF_2SSCF_2CF_2Cl$$

By reacting difluorochlorothioacetyl fluoride with sodium azide, we obtained difluorochloroacetonitrile and not the difluorochloroisothiocyanate. The course of the reaction may be illustrated by the scheme



We prepared the same difluorochloroacetonitrile for comparison by reacting the difluorochloroacetamide with phosphorous pentoxide.



$$CF_2ClC\langle^{O}_{NH_2} \xrightarrow{P_2O_5} CF_2ClCN$$

Thus, the results obtained showed that thiocarboxylic acid halides react with sodium azide to form nitriles.

EXPERIMENTAL

Preparation of trifluoromethyl isocyanate[*]. 12 g (0.185 mole) of sodium azide, activated with hydrazine hydrate, was placed in a three-necked flask fitted with two reflux condensers for low temperatures, and the flask cooled to −5°. Then through one of the condensers 35.5 g (0.2 mole) of the trifluoracetyl bromide was added to the sodium azide, while the outlet tube of the second condenser was protected from moisture with a sulfuric acid wash bottle. During the addition of trifluoracetyl bromide, the temperature in the reflux condenser was kept at about −40°. Then 400 ml of cooled toluene was added to the flask and both condensers for low temperatures were changed for one normal bulb condenser. The outlet tube from the condenser was connected to two spiral condensers, connected in series, and placed in a bath heated to 115-120° to decompose trifluoracetyl azide, partially carried along through the reflux condenser.

The condensers in their turn were connected to two traps, the first of which was cooled to −30°, and the second to −80 - −90°. The whole system was protected against moisture with a sulfuric acid wash bottle. The reaction mixture was heated for one and a half hours at 40° and then the temperature was gradually raised. At 70° gas evolution began. More vigorous evolution of gas was observed at 100°, and the reaction was carried out at this temperature for 2 hours. On further raising the temperature to 120°, the reaction was completed as indicated by no more gas evolution.

The contents of the last trap were distilled on a column for low temperatures. The yield of trifluoromethyl isocyanate was 9 g (44%). The b.p. was −35°.

Found %: C 21.5; F 51.21. C_2ONF_3.

Calculated %: C 21.62; F 51.35.

Preparation of trifluoromethylcarbamyl chloride. 4.5 g (about 0.04 mole) of trifluoromethyl isocyanate and 2.4 g (about 0.066 mole) of hydrogen chloride were placed in a glass ampule of 30 ml capacity, cooled in liquid nitrogen. Then the ampule was sealed, slowly heated to room temperature, and left overnight. The reaction occurred quietly without the evolution of heat. The reaction was easily followed by the increase in the volume of liquid, formed by the reaction of the gaseous starting materials. The next day the ampule was cooled in liquid air, opened, and the unreacted gases distilled off. The liquid left in the ampule corresponded in elementary composition and molecular refraction to trifluoromethylcarbamyl chloride. This compound was easily stored under pressure or cooled below zero; under normal conditions it noticeably decomposed. In working with trifluoromethylcarbamyl chloride it is necessary to protect it from moisture. The yield of the product was 5.8 g (99%).

n_D^{23} 1.3545, d_4^{23} 1.5551, MR_D 20.6; Calculated 20.65[**].

Found %: F 38.38; Cl 24.10. C_2HONF_3Cl.

Calculated %: F 38.6; Cl 24.1.

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[*] The experiment was carried out behind a protective screen.

[**] Here and later on, the atomic refraction of fluorine is taken as 1.25.

Preparation of trifluoromethylcarbamyl bromide. Under conditions similar to those for the reaction of trifluoromethyl isocyanate with hydrogen chloride, we obtained 3.7 g (71.5%) of trifluoromethylcarbamyl bromide from 3 g (0.027 mole) of trifluoromethyl isocyanate and 2.4 g (0.031 mole) of hydrogen bromide.

Trifluoromethylcarbamyl bromide decomposed noticeably under normal conditions, but could be stored well under pressure or in the cold. In contact with water or moist air, trifluoromethylcarbamyl bromide was quickly hydrolyzed.

n_D^{23} 1.3869, d_4^{23} 1.9489, MR_D 23.2; Calculated 23.15.

Found %: F 29.48; Br 41.70. C_2HONF_3Br.

Calculated %: F 29.7; Br 41.8.

Preparation of trifluoromethylcarbamyl fluoride. Into a stainless steel tube of 70 ml capacity was placed 1.5 g (0.075 mole) of anhydrous hydrogen fluoride and 12 g (0.1 mole) of trifluoromethyl isocyanate condensed while the tube was cooled in a mixture of acetone and dry ice.

The tube was sealed and left for 24 hours at room temperature. Then the tube was again cooled, opened, and the excess trifluoromethyl isocyanate distilled off. The yield of trifluoromethylcarbamyl fluoride was 7 g (71 %). The product was readily hydrolyzed by water.

n_D^{18} 1.2970, d_4^{18} 1.4907, MR_D 16.29; Calculated 16.32.

Found %: F 58.10; N 10.60. C_2HONF_4.

Calculated %: F 58.00; N 10.68.

Preparation of difluorochlorothioacetyl fluoride. The 2-chloro-tetrafluoroethylsulfenyl chloride required for the reaction was prepared by chlorinating dichlorooctafluorodiethyl disulfide [5].

20 g of tin foil and 40 ml of 28% hydrochloric acid were placed in a 200 ml flask with a reflux condenser about 20 cm long and 36 g (0.177 mole) of 2-chlorotetrafluoroethylsulfenyl chloride was gradually added dropwise. The contents of the reaction flask were kept boiling briskly and the temperature of the condenser at about 40°. The products distilled off during the course of the reaction were trapped in a receiver, cooled in liquid air, and then distilled on a column. The difluorochlorothioacetyl fluoride was a bright yellow liquid with an unpleasant smell. The yield was 4.1 g (15.6%). The b.p. was 36°, d_4^0 1.5183.

Found %: F 37.67; Cl 24.17; S 21.79. C_2F_3ClS.

Calculated %: F 38.3; Cl 23.9; S 21.6.

In the flask with the spent hydrochloric acid and the tin was an oil, which was separated in a separating funnel, dried with sodium sulfate, and distilled to give 8.2 g of 2,2-dichlorooctafluorodiethyl disulfide with b.p. 141°, n_D^{21} 1.3915, d_4^{21} 1.6810.

Preparation of difluorochloroacetonitrile by treating difluorochlorothioacetyl fluoride with sodium azide. 3.05 g (0.047 mole) of sodium azide, activated with hydrazine hydrate, and 7 ml of toluene were placed in a 100 ml flask, fitted with a reflux condenser and a dropping funnel, and with stirring and cooling a solution of 7 g (0.047 mole) of difluorochlorothioacetyl fluoride in 5 ml of toluene was added at such a rate that the temperature in the reaction vessel did not rise above 30-40°. Then the reaction mixture was heated to 60°; at this temperature the evolution of nitrogen began quietly and the difluorochloroacetonitrile distilled off. The yield of difluorochloroacetonitrile was 4.1 g (79%). The b.p. was −16°.

Found %: Cl 31.40; F 33.83. C_2NF_2Cl.

Calculated %: Cl 31.84; F 34.08

Preparation of difluorochloroacetonitrile by treating difluorochloroacetamide with phosphorus pentoxide. A mixture of 6.5 g (0.05 mole) of difluorochloroacetamide and 30 g (0.2 mole) of phosphorus pentoxide was placed in a round-bottomed flask of 200 ml capacity, fitted with a reflux condenser.

The top of the condenser was connected to a trap, cooled in liquid air. The pressure in the system was reduced to 100-200 mm Hg and the flask with the reaction mixture heated with a naked flame for 1 hour

Then the gaseous reaction products were distilled on a low temperature column. The yield of difluorochloroacetonitrile was 2.3 g (41%). The b. p. was −16°.

Found %: Cl 31.47; F 33.32. C_2NF_2Cl.

Calculated %: Cl 31.84; F 34.08.

SUMMARY

1. It was shown that fluorinated carboxylic acid halides react with activated sodium azide to form fluorinated alkyl isocyanates.

2. Using the reaction of difluorochlorothioacetyl fluoride with sodium azide as an example, we established that thiocarboxylic acid azides were converted into the nitriles of the corresponding acids, i.e. they did not undergo a Curtius rearrangement.

3. We developed methods for preparing thiocarboxylic acid halides and N-trifluoromethylcarbamyl halides.

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* Original Russian pagination. See C. B. translation.

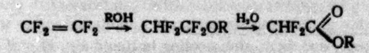
NEW METHODS OF PREPARING FLUORINATED CARBOXYLIC ACID AND ESTERS OF DIFLUOROMETHYL ALCOHOL

N. N. Yarovenko, M. A. Raksha, V. N. Shemanina and A. S. Vasilyeva

An important place in fluorine chemistry is occupied by compounds containing a perfluoroalkyl group at oxygen, sulfur, selenium, nitrogen, phosphorus, arsenic, and other atoms [1,2]. Among them there is a large number of interesting compounds obtained from the salts of trifluoracetic acid, directly and through the stage of trifluoroiodomethane, as an intermediate product [3].

Organofluorine compounds containing a difluoromethyl group are little known due to the inaccessibility of difluoracetic acid and difluoroiodomethane [1].

According to the literature data, difluoracetic acid may be prepared by oxidizing difluoroethyl alcohol [4], difluoroiodoethane CHF_2CH_2I [5] or an ether with a difluoroethyl group CHF_2CH_2OR [5], by oxidizing propylenes with a difluoromethyl group $CHF_2-CH=CCl_2$ [6], by hydrolyzing difluoracetic esters, obtained by adding alcohols to tetrafluoroethylene and then hydrolyzing them [7]



$$CF_2=CF_2 \xrightarrow{ROH} CHF_2CF_2OR \xrightarrow{H_2O} CHF_2C\overset{O}{\underset{OR}{\langle}}$$

or by fluorinating dichloracetic esters [8]: $CHCl_2CO_2R \xrightarrow{KF} CHF_2CO_2R$, as well as by hydrolyzing 2,4,6-tris-(difluoromethyl)-sym.-triazine [7]: $(CHF_2CN)_3 \longrightarrow CHF_2CO_2H$.

Difluoracetic acid may also be prepared by hydrolyzing the reaction product of sodium sulfite or bisulfite with tetrafluoroethylene [7]. However, all these methods for preparing difluoracetic acid are difficult and unsuitable for preparing large quantitites of it.

In this paper we describe a new method for preparing difluoracetic acid, based on the hydrolysis of the reaction products of tetrafluoroethylene and diethylamine, and suitable for preparative work.

Tetrafluoroethylene reacted with diethylamine under a pressure of 10-15 atm (in a glass ampule in an autoclave or metal reservoir). In bubbling carefully dried tetrafluoroethylene through diethylamine at a low pressure (1-2 atm) the reaction proceeded slowly. The product of adding diethylamine to tetrafluoro-ethylene - 1, 1, 2, 2,-tetrafluorotriethylamine - was readily distilled at low pressure. The reaction mixture, or the 1, 1, 2, 2-tetrafluorotriethylamine isolated, was then very readily hydrolyzed with water to the diethylamide of difluoracetic acid. In the first case the yield of the amide was lower than in the hydrolysis of pure tetrafluorotriethylamine. The reaction products of diethylamine and tetrafluoroethylene were not identified in previous papers [9,10]. The diethylamide of difluoracetic acid was hydrolyzed to sodium difluoracetate simply by mixing it with a dilute solution of the calculated amount of sodium hydroxide at room temperature. The conversion of the diethylamide of difluoracetic acid to the sodium salt and the isolation of pure difluoracetic acid from the latter proceeded with yields close to quantitative

$$CF_2=CF_2 \xrightarrow{HN(C_2H_5)_2} CHF_2CF_2N(C_2H_5)_2 \xrightarrow{H_2O}$$

$$CHF_2CON(C_2H_5)_2 \xrightarrow{NaOH} CHF_2CO_2Na \xrightarrow{H_2SO_4} CHF_2CO_2H$$

In the case of the diethylamide of fluorochloracetic acid it was necessary to use acidic hydrolysis.

$$CHFClCON(C_2H_5)_2 \xrightarrow{H_2SO_4} CHFClCO_2H$$

It should be noted that a large number of substituted amides of fluorinated carboxylic acids are known, but not one of them was used to prepare fluorinated acids [1,2].

We also investigated some reactions of salts of difluoracetic acid, prepared by the method described above. The reaction of sodium difluoracetate with phosphorus tribromide gave difluoracetyl bromide.

$$CHF_2CO_2Na \xrightarrow{PBr_3} CHF_2COBr$$

In reacting mercuric or silver difluoracetate with iodine the difluoroiodomethane formed partially reacted with the difluoracetic acid salt, in the reaction mixture, to form difluoromethyl difluoracetate.

$$(CHF_2CO_2)_2Hg \xrightarrow{I_2} CHF_2I \xrightarrow{(CHF_2CO_2)_2Hg} CHF_2CO_2CHF_2$$

The course of the reaction was proved by preparing difluoromethyl difluoracetate directly from di-fluoroiodomethane and mercuric difluoracetate. The reaction of difluoroiodomethane with mercuric salts of trifluoracetic, dicloracetic, and other carboxylic acids proceeded analogously.

In contrast to difluoroiodomethane, trifluoroiodomethane did not undergo exchange reactions; therefore the formation of trifluoromethyl trifluoracetate, observed in reacting trifluoracetic acid salts with iodine, may proceed only by a radical mechanism [11].

EXPERIMENTAL

Preparation of the diethylamide of difluoracetic acid. 44 g of diethylamine was placed in a stainless steel autoclave of 150 ml capacity and then, after cooling in liquid air, 40 g of tetrafluoroethylene was added. As the autoclave was slowly heated to room temperature, the pressure rose to 15-18 atm and at the end of the reaction, after 16 hours, fell to zero. With cooling and stirring, the contents of the autoclave were poured in small portions into 70 g of crushed ice. The oil precipitated was separated, dried with sodium sulfate, and distilled. The yield of the diethylamide of difluoracetic acid was 29.5 g (49%).

B. p. 97° (60 mm), n_D^{20} 1.4155, d_4^{20} 1.1180, MR_D 33.86; calculated 33.65.

Found %: C 47.76; H 7.32; N 9.06; F 24.91. $C_6H_{11}ONF_2$.

Calculated %: C 47.66; H 7.34; N 9.27; F 25.14.

The preparation of the diethylamide of difluoracetic acid proceeded through the intermediate stage of 1,1,2,2,-tetraflurotriethylamine $CHF_2CF_2N(C_2H_5)_2$. This compound is very hygroscopic and fumes strongly in air. To isolate tetrafluorotriethylamine, the addition product of diethylamine and tetrafluoroethylene was distilled under reduced pressure, carefully protecting it from moisture. The distillation could be carried out in a normal glass apparatus. The yield of tetrafluorotriethylamine was about 62.5%. The b.p. was 31° (15 mm).

Found %: C 42.73; H 6.65; N 7.50; F 44.02. $C_6H_{11}NF_4$.

Calculated %: C 41.62; H 6.40; N 8.09; F 43.89.

In carrying out the reaction with 550 g of diethylamine in a metal container of 1.3 liters capacity, connected directly to a tank of tetrafluoroethylene, the reaction mixture had to be cooled with water. Over 72 hours, the pressure in the system fell from 12 to 9.5 atm. The yield of 1,1,2,2-tetrafluorotriethylamine was 590 g (80.5% calculated on the tetrafluoroethylene reacted).

Hydrolysis of 1,1,2,2-tetrafluorotriethylamine to the amide of difluoracetic acid proceeded quantitatively.

Preparation of sodium difluoracetate. With cooling and stirring, 40 g of sodium hydroxide in 400 ml of water was added to 151 g of the diethylamide of difluoracetic acid. The reaction occurred with insignificant heat evolution. When the reaction mixture became homogeneous, first diethylamine was distilled off on a water bath and then water under reduced pressure. The yield of sodium difluoracetate was 109 g (92 %), after recrystallization from alcohol.

Found %: F 32.20. $C_2HO_2F_2Na$.

Calculated %: F 32.20.

Preparation of difluoracetic acid. 150 g of concentrated sulfuric acid was added to 118 g of sodium difluoracetate and the reaction mixture heated on an oil bath until the difluoracetic acid had completely distilled off. The yield of difluoracetic acid was 95 g (99%).

B.p. 134°, d_4^{20} 1.530, n_D^{20} 1.3419. From data [12]: B.p. 134.0°, n_4^{20} 1.3428.

Found %: F 39.18. $C_2H_2O_2F_2$.

Calculated %: F 39.58.

Preparation of difluoracetyl bromide. 27 g of phosphorus tribromide was added to 6 g of sodium difluoracetate and heated for several hours at 150°. The difluoracetyl bromide evolved during the reaction was trapped in a receiver cooled in ice-water and protected from moisture in the air. Then the distillate was redistilled on a small column. The yield of difluoracetyl bromide was 3.2 g (40%).

B.p. 48°, n_D^{20} 1.3820, d_4^{20} 1.8862.

Found %: F 23.63; Br 50.72. C_2HOF_2Br.

Calculated %: F 23.90; Br 50.28.

Preparation of mercury difluoracetate. With continuous stirring, 65 g of mercuric oxide was added in small portions to 58 g of difluoracetic acid, dissolved in 58 ml of water; heat was evolved from the reaction mixture. After adding all the mercuric oxide, the reaction mixture was allowed to stand at room temperature for half an hour. Then the solution was filtered and evaporated in vacuum on a boiling water bath. The salt obtained was carefully powdered and again heated in vacuum on a boiling water bath to constant weight. The yield of mercury difluoracetate was 106 g (91%). On heating above 210°, the salt decomposed: m.p. 185°.

Found %: Hg 51.81; F 19.57. $C_4H_2O_4F_4Hg$.

Calculated %: Hg 51.35; F 19.46.

Preparation of difluoriodomethane and difluoromethyl difluoracetate. 19.5 g of carefully dried mercuric difluoracetate was mixed with 30 g of freshly sublimed iodine and introduced in small portions into a flask, heated with a naked flame to 115-125°. The difluoroiodomethane and difluoromethyl difluoracetate evolved during the reaction were collected in a receiver cooled to −78°. The reaction was carried out at such a rate that it was possible to count the bubbles of carbon dioxide evolved, passing through a Drechsel bottle with sulfuric acid. The liquid reaction products obtained were distilled on a column. The yield of difluoroiodomethane was 6.2 g (35%). The b.p. was 22°. The yield of difluoromethyl difluoracetate was 4.5 g (61.6%).

B.p. 64°, n_D^{20} 1.300, d_4^{20} 1.5038, MR_D 18.2; calculated 17.96.

Found %: F 51.44. $C_3H_2O_2F_4$.

Calculated %: F 52.04.

This ester was prepared by the direct reaction of difluoriodomethane with mercury difluoracetate. 2.2 g of carefully dried and powdered mercury difluoracetate and 2 g of difluoroiodomethane were placed in a glass ampule. The sealed ampule was left to stand for 12 hours at room temperature. Then the ampule was opened, the mercurous iodide separated, and the liquid distilled. The yield of the difluoromethyl ester was 1.6 g (93%).

B.p. 64°, n_D^{20} 1.300, d_4^{20} 1.5038.

Preparation of fluorochloracetic acid. We prepared the diethylamide of fluorochloracetic acid required for this reaction differently from [10] by carefully bubbling trifluorochloroethylene from a gasometer at atmospheric pressure into diethylamine cooled to 0-15°, and subsequently hydrolyzing the reaction product with water. (After flushing the air from the system, the reaction of diethylamine with trifluorochloro--ehtylene proceeded to completion with the tap of the outlet tube closed.)

180 g of concentrated sulfuric acid was added to 167.5 g of the diethylamide of fluorochloracetic acid and left for 30 minutes. Then the mixture was heated on an oil bath and the reaction products with b.p. 140-165° distilled off, 50 g of concentrated hydrochloric acid was added to the distillate and the fluorochloracetic acid distilled off. The yield was 66 g (59.5%).

B.p. 162-164°, n_D^{20} 1.4100. From data [13]: b.p. 162°, n_D^{25} 1.4085.

Found %: F 17.0; Cl 31.8. $C_2H_2O_2FCl$.

Calculated %: F 16.89; Cl 31.52.

SUMMARY

1. Using the synthesis of difluor- and fluorochloracetic acids as examples, we describe a new method of preparing fluorinated carboxylic acids based on the hydrolysis of the reaction products of fluorinated olefins with diethylamine. It was shown that the reaction of diethylamine and tetrafluoroethylene gave 1,1,2,2--tetrafluorotriethylamine.

2. It was established that the reaction of difluoroiodomethane and mercuric and silver salts of carboxylic acids gave esters of difluoromethyl alcohol.

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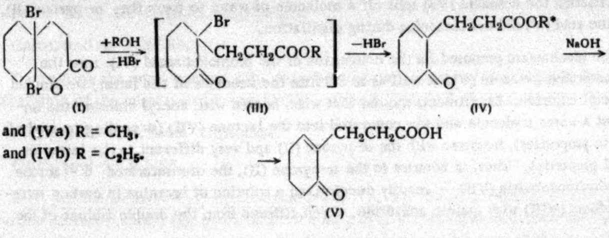
δ -LACTONES

X.* 9,10- DIBROMOOCTAHYDROCOUMARIN AND ITS REACTIONS

N. P. Shusherina, M. Yu. Lurye and R. Ya. Levina

In previous investigations we showed that unsaturated δ-lactones (δ-enol lactones) add bromine to form extremely reactive dibromolactones, from which α-pyrones [1] may be obtained by distillation, and bromoketoacids and their esters [2,3] by reaction with water and alcohols. 9,10-Dibromooctahydrocoumarin (I), which we described previously, was readily converted into 5,6-cyclohexano-α-pyrone (II) (5,6,7,8-tetrahydrocoumarin) in an 82% yield by distillation in vacuum [1].

In this work we studied other reactions of 9,10-dibromooctahydrocoumarin (I) - its reactions with alcohols and water. It was shown that the dibromolactone (I) readily reacted in the cold with alcohols (ethyl and methyl) to break the lactone ring and form esters (IIIa and IIIb) corresponding to γ-bromo-δ-keto-acids; when distilled the latter readily split off hydrogen bromide and were converted to esters (IVa and IVb) of an unsaturated ketoacid (V), and by hydrolyzing the esters the unsaturated ketoacid (V) - 2-(β-carboxyethyl)-cyclohexen-2-one-1 - itself was obtained.



(IIIa) and (IVa) R = CH_3,
(IIIb) and (IVb) R = C_2H_5.

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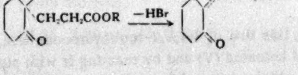
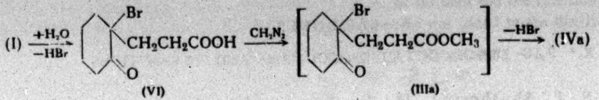
* For Reports VIII and IX see: Proc. Acad. Sci. USSR 113,820,113,1084(1957).(See C.B. Translation).

** The hydrogen bromide could also be split off in another way to form esters with a semicyclic double bond

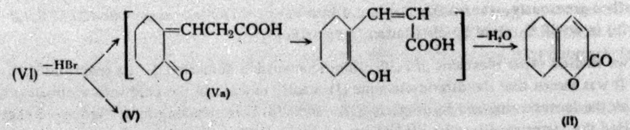


However, the unsaturated ketoacid (V) we obtained had different properties from the ketoacid with a semicyclic double bond (Va) described in the literature [4].

It was then established that the dibromolactone (I) reacted with water, when the lactone ring was broken, to give a crystalline γ-bromo-δ-ketoacid - 2-bromo-2-(β-carboxyethyl)-cyclohexanone (VI); the yield was 78%. The bromoketoacid (VI) reacted with diazomethane, forming a methyl ester (IIIa) which split off hydrogen bromide on distillation and was converted into the methyl ester of an unsaturated ketoacid, identical with the one described above (IVa).

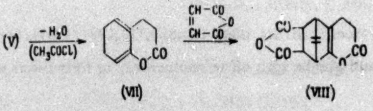


When distilled in vacuum the bromoketoacid (VI) was converted into 5,6-cyclohexano-α-pyrone (II) and an unsaturated ketoacid*; which was found to be identical with the acid (V).



Thus in contrast to esters of bromoketoacids (IIIa and IIIb), the bromoketoacid (VI) itself split off hydrogen bromide in two ways when distilled, with the formation of unsaturated ketoacids (V) and (Va); under the conditions of the distillation the ketoacid (Va) split off a molecule of water to form the α-pyrone (II), while at the same time the acid (V) did not lactonize during distillation.

In order to prove the mechanism proposed for the conversion of the bromoketoacid (VI) into the α-pyrone (II) and the unsaturated ketoacid (V), as well as to confirm the structure of the latter, we studied its lactonization with acetyl chloride. Experiments showed that when heated with acetyl chloride the unsaturated ketoacid (V) lost a water molecule and was converted into the lactone (VII) (according to analysis data and absence of acidic properties), isomeric with the α-pyrone (II) and very different to the latter in its physical and chemical properties. Thus, in contrast to the α-pyrone (II), the diunsaturated δ-lactone obtained - 3,4,6,7-tetrahydrocoumarin (VII) - readily decolorized a solution of bromine in carbon tetrachloride and formed an adduct (VIII) with maleic anhydride, which differed from the double adduct of the α-pyrone (II) [1,4].



The structure of the lactone (VII), like that of 3,4,6,7-tetrahydrocoumarin, was also confirmed by hydrolyzing it to the starting unsaturated ketoacid (V) and by reacting it with piperdine, which resulted in a piperidide (IX), identical with the piperidide prepared from the ester of the unsaturated ketoacid (IVb).

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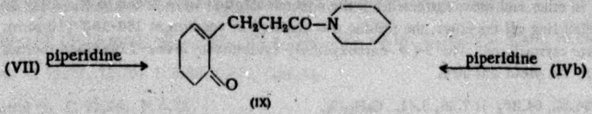
*By reacting the bromoketoacid (VI) with acetyl chloride in the cold followed by distillation of the reaction mixture, we obtained only the α-pyrone (II) in a 74% yield.



(IX)

With the exception of (II), all the substances obtained are not described in the literature.

EXPERIMENTAL

2-(β-Carbethoxyethyl)-cyclohexen-2-one-1 (IVb). 16 g of bromine was added dropwise to a solution of 15.2 g of $\Delta^{9,10}$-hexahydrocoumarin [5,6], cooled to −20°, and stirred. After evaporating off the ether in vacuum in a stream of dry air, the residual crystalline dibromolactone (I) was treated in the cold with 25 ml of anhydrous ethyl alcohol; the mixture gave off heat. After standing for half an hour, the reaction mixture was poured into water and the oily layer of the ethyl ester of the bromoketoacid (IIIb), which separated, was dissolved in ether. After drying the ether solution with magnesium sulfate and distilling off the ether, the residue was distilled in vacuum (twice); hydrogen bromide was split out and 2-(β-carbethoxyethyl)-cyclohexen-2-one-1 distilled over; the yield was 50%.

B. p. 148-149° (10 mm), n_D^{20} 1.4945, d_D^{20} 1.0882; MR_D 52.53. $C_{11}H_{16}O_3F$. Calc. 51.99.

Found %: C 67.76, 67.78; H 8.18, 8.32. $C_{11}H_{16}O_3$.

Calculated %: C 67.33; H 8.20.

Semicarbazone: m.p. 125-126° (from alcohol).

Found %: N 16.71, 16.82. $C_{12}H_{19}O_3N_3$.

Calculated %: N 16.60.

On treating the ester isolated with an equimolecular amound of piperidine in the cold, we obtained the piperidide of the unsaturated ketoacid (IX) with m.p. 140-141° (from alcohol).

Found %: N 6.24, 6.42. $C_{14}H_{21}O_2N$.

Calculated %: N 5.95.

2-(β-Carbomethoxyethyl)-cyclohexen-2-one-1 (IVa). 25 ml of methyl alcohol was added to the crystalline dibromolactone (I), prepared from 12.4 g of $\Delta^{9,10}$-hexahydrocoumarin and the reaction mixture stirred for half an hour; on adding water an oily layer of the methyl ester of the bromoketoacid separated, which split out hydrogen bromide on distillation and was converted into 2-(β-carbomethoxyethyl)-cyclo-hexen-2-one-1 (60.0% yield).

B. p. 149-150° (13 mm), n_D^{20} 1.4930, d_4^{20} 1.1092, MR_D 47.78. $C_{10}H_{14}O_3F$. Calc. 47.37.

Found %: C 65.84, 65.77; H 7.83, 7.83. $C_{10}H_{14}O_3$.

Calculated %: C 65.91; H 7.74.

Semicarbazone: m.p. 128° (from alcohol).

Found %: C 55.26, 55.38; H 7.34, 7.30. $C_{11}H_{17}O_3N_3$.

Calculated %: C 55.23; H 7.11.

2-(β-Carboxyethyl)-cyclohexen-2-one-1 (V). A mixture of 11.7 g of 2-(β-carbethoxyethyl)-cyclo-hexen-2-one-1 (IVb) and 40 ml of 10% aqueous sodium hydroxide solution was boiled until the oily layer completely dissolved (4 hours). The reaction mixture was extracted with ether to remove unreacted ester of the unsaturated ketoacid and then acidified with concentrated hydrochloric acid. The oil which separated was dissolved in ether, and ether extracts from the aqueous solution were added to it. After drying the ether solution and distilling off the ether, the residue was distilled in vacuum at 180-185° (10 mm). On standing the distillate crystallized. The 2-(β-carboxyethyl)-cyclohexen-2-one-1 obtained melted at 74-75° (from benzine); the yield was 60%.

Found %: C 64.22, 64.35; H 7.26, 7.41. $C_9H_{12}O_3$.

Calculated %: C 64.24; H 7.19.

The 2,4-dinitrophenylhydrazone of the unsaturated ketoacid obtained melted at 200-202° (from ethyl acetate).

Found %: C 51.35, 51.33; H 4.91, 4.90. $C_{15}H_{16}O_6N_4$.

Calculated %: C 51.70; H 4.62.

Semicarbazone: m. p. 180-181° (from alcohol).

Found %: N 18.52, 18.25. $C_{10}H_{15}O_3N_3$.

Calculated %: N 18.65.

2-Bromo-2-(β-carboxyethyl)-cyclohexanone (VI). Dry, white crystals of the dibromolactone (I), prepared from 15.2 g of $\Delta^{9,10}$-hexahydrocoumarin, were stirred with 150 ml of cold water. At first the crystals were converted into an oil which gradually crystallized on cooling to 0-5°. After drying in a vacuum desiccator, we obtained 18.3 g (73%) of the bromoketoacid (VI) with m.p. 60-62° and m.p. 70-71° after 3 recrystallizations from benzine.

Found %: C 43.28, 43.22; H 5.39, 5.48. $C_9H_{13}O_3Br$.

Calculated %: C 43.35; H 5.26.

We were unable to obtain the bromoketoacid (VI) in a pure state by the method of bromination of 2-(β-carboxyethyl)-cyclohexanone with dioxan dibromide.

The bromoketoacid (VI) reacted vigorously with an ether solution of diazomethane to form the methyl ester (IIIa), which split out hydrogen bromide on distillation and formed 2-(β-carbomethoxyethyl)-cyclo-hexen-2-one-1 (IVa), which was identical with the methyl ester obtained by reacting the dibromolactone I with methyl alcohol: b.p. 141-142° (8-10 mm), n_D^{20} 1.4920, d_4^{20} 1.1100.

5,6,7,8-Tetrahydrocoumarin (5,6-cyclohexano-α-pyrone) (II). A mixture of 11.2 g of the bromoketo-acid (VI) and 30 g of acetyl chloride was left at room temperature for 3 hours; then the acetyl chloride was evaporated off in vacuum and the residue distilled. The distillate with b.p. 148-150° (10 mm) obtained almost completely crystallized on standing. After treatment with 5% sodium hydroxide and recrystallization from alcohol, the 5,6-cyclohexano-α-pyrone (II) (yield 76%) melted at 61-62°. Literature data [4]: m.p. 64.5-65°. A mixed melting point with the α-pyrone formed on distilling the dibromide (I) [1] was not depressed.

Distillation of the bromoketoacid (VI) gave the α-pyrone (II) and the unsaturated ketoacid (V). 10 g of the bromoketoacid (IV) was distilled in vacuum; hydrogen bromide was split out and we obtained 4.5 g of a distillate with b.p. 148-180° (10 mm), which was treated with a cold 10% aqueous solution of sodium hydroxide. The undissolved crystals were filtered off (yield 30%) and had m.p. 62-63° (from alcohol); according to its properties the substance obtained was 5,6-cyclohexano-α-pyrone (II).

The alkaline solution was extracted with ether to remove traces of the α-pyrone, acidified with concentrated hydrochloric acid, and again extracted with ether. From the ether extract we isolated 2.3 g (34.3%) of a substance, which crystallized on standing, and was the unsaturated ketoacid - 2-(β-carboxy-ethyl)-cyclohexen-2-one-1 (V), with m.p. 77-78° (from benzine). A mixed melting point with the unsaturated ketoacid, prepared by hydrolyzing the ethyl ester (IVa) was not depressed.

3,4,6,7-Tetrahydrocoumarin (VII). 3.4 g of the unsaturated ketoacid (V) was heated with 10 ml of acetyl chloride for 24 hours; the acetyl chloride was evaporated off in vacuum and the residue distilled.

The 3,4,6,7-tetrahydrocoumarin obtained (yield 66.6%) had the following constants:

B. p. 139-140° (8-10 mm), n_D^{20} 1.5290, d_4^{20} 1.1520, MR_D 40.18. $C_9H_{10}O_2{\vDash}_2$. Calc. 40.08.

Found %: C 71.79, 71.70; H 6.80, 6.82. $C_9H_{10}O_2$.

Calculated %: C 71.94; H 6.71.

The substance instantly decolorized a solution of bromine in carbon tetrachloride and was not titrated by alkali; on heating it dissolved in an aqueous solution of alkali; on acidification of the solution a substance separated, which gave a 2,4-dinitrophenylhydrazone (m. p. 201°), identical with the 2,4-dinitrophenylhydrazone of the unsaturated ketoacid (V). 3,4,6,7-Tetrahydrocoumarin gave a piperidide (IX) with m.p. 139-140° (from alcohol); a mixed melting point with the piperidide prepared from the unsaturated ester (IVa) was not depressed.

Adduct of 3,4,6,7-tetrahydrocoumarin with maleic anhydride (VIII). A solution of 0.6 g of 3,4,6,7-tetrahydrocoumarin and 0.4 g of maleic anhydride in 2 ml of anhydrous xylene was boiled for 6 hours. On standing, the solution deposited crystals of the adduct (yield 30%) with m.p. 179-180° (from acetone + +petroleum ether).

Found %: C 63.01, 63.08; H 5.05, 4.88. $C_{13}H_{12}O_5$.

Calculated %: C 62.88; H 4.86.

SUMMARY

1. The reaction between 9,10-dibromooctahydrocoumarin and alcohols proceeded with breaking of the lactone ring and resulted in esters of γ-bromo-δ-ketoacids (IIIa and IIIb), which split out hydrogen bromide on distilling and were converted into esters of an unsaturated ketoacid (IVa and IVb). We thus obtained 2-(β-carboxyethyl)- and 2-(β-carbomethoxyethyl)-cyclohexene-2-one-1.

2. Reaction of 9,10-dibromooctahydrocoumarin with water gave a γ-bromo-δ-ketoacid – 2-bromo-2-(β-carboxyethyl)-cyclohexanone.

3. When treated with acetyl chloride the γ-bromo-δ-ketoacid (VI) was converted into 5,6,7,8-tetrahydrocoumarin (5,6-cyclohexano-α-pyrone).

4. When distilled, the γ-bromo-δ-ketoacid (VI) split out hydrogen bromide and was converted into 5,6-cyclohexano-α-pyrone and 2-(β-carboxyethyl)-cyclohexen-2-one-1.

5. When treated with acetyl chloride 2-(β-carboxyethyl)-cyclohexen-2-one-1 was converted into a diunsaturated δ-lactone – 3,4,6,7-tetrahydrocoumarin.

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δ - LACTONES

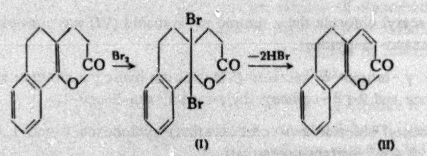
XI. 9,10-DIBROMO-7,8-BENZOHEXAHYDROCOUMARIN AND ITS REACTIONS

N. P. Shusherina, R. Ya. Levina and L. V. Kondratyeva

It was shown in our previous reports [1,2] that when heated 9,10-dibromooctahydrocoumarin split out two molecules of hydrogen bromide to form 5,6-cyclohexano- α-pyrone [1] and readily reacted in the cold with water and alcohols to open the lactone ring and form a γ-bromo-δ-ketoacid and its esters [2].

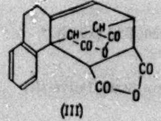
In this work we studied the reactivity of 9,10-dibromo-7,8-benzohexahydrocoumarin (I), which was prepared by brominating a tricyclic unsaturated δ-lactone (7,8-benzo- $\Delta^{9,10}$-tetrahydrocoumarin, synthesized from monocyanethylated α-tetralone by a method we developed previously [3,4]).

It seemed interesting to study the reaction of this dibromolactone to establish the limits of applicability of the new methods we developed previously [1,2,5] for the preparation of α-pyrones, γ-bromo-δ-ketoacids and their esters. We established that when distilled 9,10-dibromo-7,8-benzohexahydrocoumarin (I), the same as 9,10-dibromooctahydrocoumarin [1], split out hydrogen bromide and was converted into the corresponding α-pyrone - 7,8-benzo-5,6-dihydrocoumarin (II) in 88 % yield.



(I) (II)

The structure of the α-pyrone (II) was confirmed by its reaction with maleic anhydride as well as with ammonia and primary and secondary amines. The reaction of the α-pyrone (II) with maleic anhydride was accompanied by CO_2 evolution and gave a double adduct (III) [15% yield, calculated on the α-pyrone (II) used and 35 % - on the pyrone reacted]. Attempts to increase the adduct yield by more drastic reaction conditions resulted in resinification of the α-pyrone. By heating adduct (III) with aqueous alkali solution followed by acidification we obtained acid (IV), which was converted into the tetramethyl ester (V) when treated with diazomethane.



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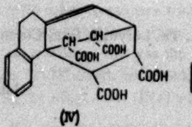

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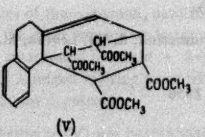
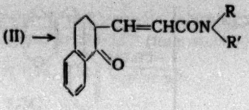
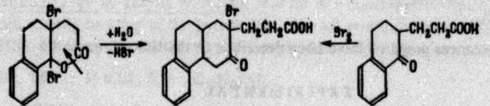


(V)

The α-pyrone (II) reacted readily in the cold with ammonia and primary and secondary amines to open the pyrone ring and form crystalline amides - the piperidide (VI), diethylamide (VII), anilide (VIII), and amide (IX) - of β-(tetralon-1-yl-2)-acrylic acid in 75-100% yields.

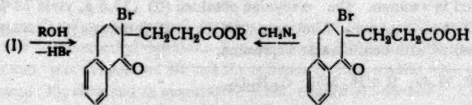


We then studied the reaction of the dibromolactone (I) with water in the cold; the reaction product was a γ-bromo-δ-ketoacid - 2-bromo-2(β-carboxyethyl)-tetralone-1 (X); the yield was quantitative. The structure of the bromoketoacid (X) prepared by this method was confirmed by synthesis by brominating 2-(β-carboxyethyl)-tetralone-1[3] with dioxan dibromide.



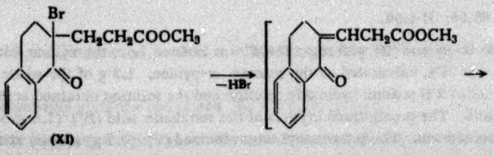
(I) (X)

The reaction of the dibromolactone (I) with alcohols in the cold gave esters of a γ-bromo-δ-ketoacid - - 2-bromo-2-(β-carbomethoxyethyl)-tetralone-1 (XI), and 2-bromo-2-(β-carbethoxyethyl)-tetralone-1 (XII) (81 and 70% yields). The structure of the esters obtained was proved by the synthesis of one of them (XII) by treating the γ-bromo-δ-ketoacid (X) with diazomethane.



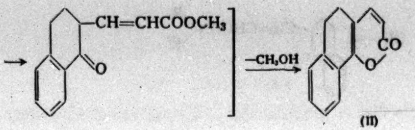
R=CH$_3$ (XI), R=C$_2$H$_5$ (XII)

The esters of the γ-bromo-δ-ketoacids have unusual chemical properties. Thus the ester (XI) reacted readily in the cold with secondary amines (diethylamine and piperidine), forming substituted amides (VI and VII) of tetralonylacrylic acid [identical with those obtained by reacting the same amines with the α-pyrone (II)]. On distillation with a tertiary amine (diethylaniline), the ester (XI) readily split out a molecule of hydrogen bromide and alcohol and was converted into the α-pyrone (II)* in 87% yield.



(XI)

***It gave the same derivatives with maleic anhydride and amines as the α-pyrone (II), prepared by distilling the dibromolactone (I).**



(II)

Thus distillation of the ester of the γ - bromo-δ -ketoacid (XI) with diethylaniline, the same as distillation of the dibromolactone (I), may serve as a method for preparing the tricyclic α-pyrone: 7,8-benzo-5,6-dihydrocoumarin.

None of the substances prepared have been described in the literature.

EXPERIMENTAL

9,10-Dibromo-7,8-benzohexahydrocoumarin (I). 20 g of bromine was added dropwise to a solution of 25 g of 7,8-benzo-$\Delta^{9,10}$-tetrahydrocoumarin (m.p. 74-75°) [3,4] in 180 ml of ether, which was stirred and cooled to −5° to −10°. After evaporating off the ether in vacuum, we obtained a quantitative yield of a crystalline dibromolactone (m.p. 67-68°), which readily split out hydrogen bromide (fuming strongly in air) and therefore could not be analyzed.

7,8-Benzo-5,6-dihydrocoumarin (II) and its reactions. 28 g of the dibromolactone (I) was carefully heated in a stream of dry air for 20-30 minutes, so that the hydrogen bromide could be split out more completely, and then distilled in vacuum. The α-pyrone obtained (II) (13.5 g, yield 88 %) had b.p. 218-220° at 20 mm; m. p. 75-76° (from benzine). A mixture with the starting unsaturated lactone (7,8-benzo-$\Delta^{9,10}$-tetrahydrocoumarin) melted with considerable depression.

Found %: C 78.49, 78.49; H 4.96, 5.09. $C_{13}H_{10}O_2$.

Calculated %: C 78.76; H 5.06.

The adduct of 7,8-benzo-5,6-dihydrocoumarin and maleic anhydride (III). A mixture of 5.4 g (0.027 mole) of the α-pyrone (II) and 5.4 g (0.054 mole) of maleic anhydride in 10 ml of xylene was boiled for 4 hours, until CO_2 was no longer evolved. The precipitated crystals (1.4 g, 15% yield) of the adduct (III) melted at 316-318° (in a sealed capillary) after recrystallization from acetone with petroleum ether added.

Found %: C 68.26, 68.28; H 4.15, 4.23. $C_{20}H_{14}O_6$.

Calculated %: C 68.56; H 4.00.

3.1 g of unreacted α -pyrone (II) with m.p. 73-74° was isolated from the xylene solution. Thus the yield of the adduct (III) was 35%, calculated on the reacted α-pyrone. 1.3 g of the adduct (III) was dissolved by heating in 10 ml of 2 N sodium hydroxide solution and the solution obtained acidified with concentrated hydrochloric acid. The precipitated crystals of the tetrabasic acid (IV) (1.4 g) were treated with an ether solution of diazomethane. The tetramethyl ester obtained (V) (0.7 g) melted at 169-170° (from alcohol).

Found %: C 65.21, 65.07; H 6.17, 6.14. $C_{24}H_{26}O_8$.

Calculated %: C 65.14; H 5.92.

Piperidide of β-(tetralon-1-yl-2)-acrylic acid (VI). With stirring, 2.6 g (0.031 mole) of piperidine was added to 5 g (0.025 mole of α-pyrone (II); the mixture obtained was left for 20 minutes and then 10 ml of water added to it. The crystals of the piperidide (VI) precipitated (yield 96%) melted at 162-163° (from alcohol).

Found %: C 76.20, 76.05; H 7.80, 7.61. $C_{18}H_{21}O_2N$.

Calculated %: C 76.32; H 7.48.

The diethylamide of β-(tetralon-1-yl-2)-acrylic acid (VII) was prepared in 93% yield by the same method as for the piperidide and melted at 136-137° (from alcohol).

Found %: C 75.20, 75.46; H 7.74, 7.80. $C_{17}H_{21}O_2N$.

Calculated %: C 75.23; H 7.74.

Anilide of β-(tetralon-1-yl-2)-acrylic acid (VIII). A mixture of 0.5 g of the pyrone (II) and 0.23 g of aniline was stirred until it formed an oil and was left for 5-6 hours. On standing, the oil crystallized. The anilide obtained (VIII) (yield 75%) melted at 164-165° (from alcohol).

Found %: C 77.90, 78.01; H 6.07, 6.13. $C_{19}H_{17}O_2N$.

Calculated %*: C 78.33; H 5.85.

Amide of β-(tetralon-1-yl-2)-acrylic acid (IX). 0.5 ml of a concentrated aqueous solution of ammonia was added with stirring to 0.5 g of the pyrone (II). The oil precipitated quickly crystallized on standing. The amide (IX), obtained in quantiative yield, melted at 106-107°.

Found %: C 72.80, 73.02; H 6.21, 6.28. $C_{13}H_{13}O_2N$.

Calculated %**: C 72.55; H 6.09.

2-Bromo-2-(β-carboxyethyl)-tetralone-1 (X). 45 g of the dibromolactone (I) was stirred with 100 ml of cold water. The reaction was complete in 20-30 minutes. The white crystals formed were filtered off, washed with water on the filter, and dried in a vacuum desiccator. The 2-bromo-2-(β-carboxyethyl)-tetralone-1 (X), obtained in quantitative yield, melted at 143° (from ether).

Found %: C 52.20, 52.45; H 4.44, 4.55. $C_{13}H_{13}O_3Br$.

Calculated %: C 52.57; H 4.41.

Synthesis of 2-bromo-2-(β-carboxyethyl)-tetralone-1. 6 g of dioxan dibromide was gradually added to a solution of 5 g of 2-β-carboxyethyl-tetralone-1 [4] in 20 ml of dioxan. The reaction mixture was left overnight. The dioxan was evaporated off and the residual crystals washed with water, filtered off, and dried. The bromoketoacid (X), obtained in quantiative yield, melted at 142-143°. A mixture with the preparation of bromoketoacid, obtained from the dibromolactone (I), melted without depression.

2-Bromo-2-(β-carbomethoxyethyl)-tetralone-1 (XI) and its reactions. 15 ml of methyl alcohol was added to 5 g of the dibromolactone (I); the dibromide completely dissolved in the alcohol with strong evolution of heat. After standing for 30 minutes, 100 ml of water was added to the solution, the oil that separated dissolved in ether, and the solution dried with calcium chloride. After evaporating off the ether, the residual oil crystallized on standing. The methyl ester*** (XI) obtained (3.5 g, 81% yield) melted at 42° (from petroleum ether).

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*For the second possible reaction product - the corresponding N-phenylpyridone calculated %: C 83.50; H 5.49.

**For the corresponding pyridone calculated %: C 79.20; H 5.58.

***The ethyl ester was prepared in the same way: 2-bromo-2-(β-carbethoxyethyl)-tetralone-1 (XII). 20 ml of anhydrous ethyl alcohol was added to 8 g of the dibromolactone (I); there was strong evolution of heat and the dibromide completely dissolved. On standing for 24 hours at 0-5°, the solution deposited crystals of the ethyl ester (XII) (5.4 g, yield 70%); m.p. 38-39° (from petroleum ether).

Found %: C 54.35, 54.39; H 4.96, 5.14. $C_{14}H_{15}O_3Br$.

Calculated %: C 54.01; H 4.85.

The synthesis of the ester (XI) was achieved by treating the bromoketoacid (X) with diazomethane. 150 ml of an ether solution containing ~0.09 mole of diazomethane was gradually added to 15 g of the bromoketoacid (X). At the end of the reaction, the ether was evaporated off in vacuum; the residual oil crystallized on standing in the cold. The methyl ester obtained (12.2 g, yield 78%) melted at 42-42.5° (from petroleum ether). A mixture with the methyl ester (XI), obtained from the dibromolactone (I), did not show depression of melting point.

Treatment of 2-bromo-2-(β-carbomethoxyethyl)-tetralone-1 (XI) with diethylaniline (with heating). A mixture of 7 g (0.022 mole) of the ester (XI) and 4.6 g (0.036 mole) of diethylaniline was boiled for 30 minutes, then the diethylaniline was distilled off in vacuum and the residue distilled at 198-205° (20 mm). The oil obtained (4 g, yield 87%) quickly crystallized; m. p. 75-76° (from benzene). The substance did not contain halogen, did not decolorize bromine water, and gave the same derivatives with piperidine, di-ethylamine, ammonia, and maleic anhydride as benzodihydrocoumarin (II). A mixture with benzodihydro-coumarin (II), prepared by distillation of the dibromolactone (I), melted without depression. Thus, the substance obtained was 7,8-benzo-5,6-dihydrocoumarin (II).

Found %: C 78.60, 78.52; H 5.20, 5.20. $C_{13}H_{10}O_2$.

Calculated %: C 78.76; H 5.06.

On distilling the bromoester (XI) in vacuum in the absence of diethylamine, benzodihydrocoumarin was also formed, but in lower yield.

Treatment of 2-bromo-2-(β-carbomethoxyethyl)-tetralone-1 (XI) with piperidine. 4 g (0.04 mole) of piperidine was added to 5 g (0.016 mole) of the methyl ester (XI). The bromoester quickly dissolved with strong evolution of heat. On adding water to the solution, an oil separated and crystallized (yield 82%), m. p. 162-163° (from alcohol). A mixed melting point with the piperidide (VI), prepared from benzodihydrocoumarin, was not depressed.

Treatment of the ester (XI) with diethylamine. 2.9 g (0.04 mole) of diethylamine was added to 5 g (0.016 mole) of the ester (XI). The mixture heated up strongly and the ester (XI) completely dissolved and then the solution deposited crystalline ethylamine hydrobromide, which dissolved on adding water. The oil, which separated from this solution, crystallized on standing (yield 80%), m. p. 136-137° (from alcohol). A mixed melting point with the diethylamide (VII), obtained from benzodihydrocoumarin (II), was not depressed.

SUMMARY

1. When distilled, 9,10-dibromo-7,8-benzohexahydrocoumarin split out two molecules of hydrogen bromide and was converted into a α-pyrone - 7,8-benzo-5,6-dihydrocoumarin in 88% yield.

2. Reaction of dibromobenzohexahydrocoumarin with water gave a γ-bromo-δ-ketoacid: 2-bromo-2-(β-carboxyethyl)-tetralone-1 (quantitative yield).

3. Dibromobenzohexahydrocoumarin reacted in the cold with alcohols to form esters of the same γ-bromo-δ-ketoacid (70-80% yield).

4. When heated with diethylaniline the methyl ester of 2-bromo-2-(β-carboxyethyl)-tetralone-1 was converted into 7,8-benzo-5,6-dihydrocoumarin in 87% yield.

5. Reaction of the methyl ester of 2-bromo-2-(β-carboxyethyl)-tetralone-1 with secondary amines gave substituted amides of tetralonylacrylic acid.

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CHEMISTRY OF SELENOPHENE

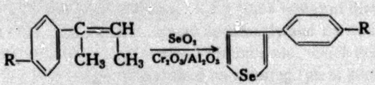
VII. SYNTHESIS AND ACETYLATION OF 3-ARYLSELENOPHENES AND 2,3-BENZOSELENOPHENES

Yu. K. Yuryev, N. N. Mezentsova, T. A. Melentyeva and E. G. Treshchova

In a previous report by one of us [1] a new method for the synthesis of selenophene and its homologs was described, using the reaction of paraffinic, ethylenic and diene hydrocarbons, having at least four carbon atoms in a straight chain, with selenium dioxide in the presence of chromic oxide on aluminum oxide at 500-550° in an atmosphere of nitrogen. In this way the following were prepared: selenophene — from n-butane, a mixture of butenes and butadiene-1,3; 3-methylselenophene — from 2-methylbutene-2 and 2-methylbutene-3; 3,4-dimethylselenophene — from 2,3-dimethylbutene-2 and 2,3-dimethylbutadiene-1,3.

Of the arylated selenophenes, there is a description in the literature of 2,4-diphenylselenophene and its derivatives with substitutents on the benzene nucleus, that are interesting from the biological point of view; these compounds were synthesized by reacting anils of aliphatic-aromatic ketones with selenium [2,4].

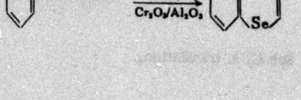
In the present work we used Yuryev and Khmelynitsky's method [1], mentioned above, for the synthesis of monoarylselenophenes, and by reducing selenium dioxide with 2-phenylbutene-2 in the presence of chromic oxide on aluminum oxide at 450° we obtained 3-phenylselenophene. We obtained 3-p-tolylselenophene from 2-p-tolylbutene-2 under similar conditions.



(R = H, CH_3)

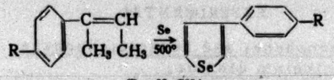
The yields of the above β-arylselenophenes were small and were 12.5 and 9.5 %, respectively, calculated on the hydrocarbon reacting. The reason for this was a side reaction — cracking of the starting arylalkenes, which resulted in the formation of a considerable amount of a hydrocarbon mixture, composed of benzene, toluene, ethylbenzene, isopropylbenzene, n-propylbenzene, and 1,4-methylethylbenzene. The composition of the hydrocarbon mixtures was established by studying the combination scattering spectra of narrow fractions, isolated by distillation on a column. As far as the preparation of 2-phenylselenophene from 1-phenylbutene-3 is concerned, under the conditions given above it formed only in a very small yield as the facile aromatization of the hydrocarbon, forming mainly naphthalene, became the main process.

The formation of 2,3-benzoselenophene by closing of the selenophene ring, in which the carbon atoms in positions 2 and 3 were at the same time members of the benzene nucleus, was achieved by reducing selenium dioxide with styrene under the same conditions.



We also tried to prepare the above arylselenophenes by treating the same arylalkenes with selenium at high temperature, similarly to the preparation of their analogs in the thiophen series, by treating arylalkenes with heated sulfur [5]. Using this general method, B. A. Arbuzon [6] synthesized selenophene, 2-methylselenophene and 2,5-dimethylselenophene from butadiene-1,3, pentadiene-1,3, hexadiene-2,4, and selenium, respectively, at 380-420°.

By reacting 2-phenylbutene-2 and 2-p-tolylbutene-2 with selenium at 500° in the present work we obtained 3-phenylselenophene and 3-p-tolylselenophene in 30 and 10% yields, respectively, calculated on the hydrocarbon reacting.

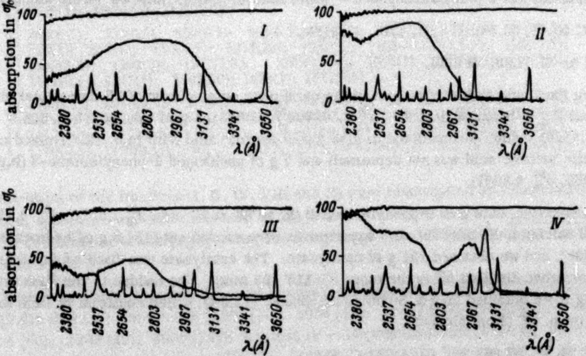


(R = H, CH$_3$)

Very little cracking of hydrocarbons occurred in this method of 3-arylselenophene preparation. However, it should be noted that the attempt to obtain 2-phenylselenophene by this method from 1-phenylbutene-3 was unsuccessful: the hydrocarbon was partially aromatized to form naphthalene and a large part of the 1-phenylbutene-3 was recovered unchanged from the reaction.

An attempt to prepare benzoselenophene by reacting styrene with selenium at 450 and 500° was likewise unsuccessful: the styrene was recovered unchanged from the reactor.

Thus in the reactions of alkenes, in particular arylalkenes, with selenium (as in their catalytic reaction with selenium dioxide [1]), the most favorable hydrocarbon structure for closing the selenophene ring is that with a centrally placed double bond in a straight, four carbon side chain possibly with a greater degree of substitution at the carbon atoms connected by the double bond. The structure of the 2-phenylbutene-2 which we used and, even to a greater degree, that of 2,3-diphenylbutene-2 and 2-methyl-3-phenylbutene-3 satisfy these requirements.



Absorption spectra of: 2-phenylselenophene (I), 3-phenylselenophene (II), 3-p-tolylselenophene (III), and 2,3-benzoselenophene (IV).

The 3-arylselenophenes and 2,3-benzoselenophene we obtained were acylated with silicoacetic anhydride by the method developed by one of us [7], and as a result we obtained 2-acetyl-3-phenylselenophene (27%), 2-acetyl-3-p-tolylselenophene (31%) and 2-acetyl-4,5-benzoselenophene (69%).

A comparison of the absorption spectra curves in the ultraviolet region obtained for 2-phenylselenophene, 3-phenylselenophene, 3-p-tolylselenophene and 2,3-benzoselenophene (Figure) showed that the character of the curve was determined mainly by the ring containing selenium*. The position of the aryl radical in the selenophene ring affected the absorption spectrum: in going from 2-aryl- to 3-arylselenophene the absorption band was displaced toward shorter wavelength; thus λ_{max} was 289 mμ for 2-phenylselenophene, while for 3-phenylselenophene λ_{max} was 272 mμ. The presence of a substituent in the benzene ring, apparently, hardly affected the absorption region.

The absorption spectrum of benzoselenophene differed sharply from the arylselenophene spectra by the presence of a clearly expressed oscillation structure of the absorption band.

EXPERIMENTAL

Preparation of arylselenophenes and benzoselenophene from arylalkenes and selenium dioxide.

Experimental method. 50 g (~80 ml) of chromic oxide on aluminum oxide (20% Cr_2O_3) was placed in a silica tube with an internal diameter of 20 mm. The hydrocarbon was introduced at a rate of 0.14 ml/min directly into the reaction zone by a tube, which lead to the catalyst bed. Selenium dioxide (0.2 mole) was placed in the first part of the tube, protruding from the furnace, and heated to 315-320°. The selenium dioxide subliming was carried along into the reaction zone, heated to 450°, with a stream of nitrogen, passed at a rate of 80-90 ml/min. The catalyzate entered a receiver with a reflux condenser.

2-Phenylselenophene. 26.4 g of 1-phenylbutene-3 (b.p. 114° at 108 mm, n_D^{20} 1.5070, d_4^{20} 0.8915) was reacted with 22 g of selenium dioxide. In all, 3 experiments were carried out (79.2 g of hydrocarbon, 66 g of selenium dioxide) and we obtained 48 g of catalyzate. A liquid hydrocarbon fraction was distilled off from the catalyzate in vacuum in the range 95-110° at 35 mm (20 g); the solid residue left in the flask was steam distilled and we obtained 25 g of a substance with m. p. 70° (from alcohol). Analysis data showed that the substance with m. p. 70° was a mixture of naphthalene and 2-phenylselenophene. On distilling this mixture in vacuum, at first the naphthalene distilled off with b.p. 102-103° (20 mm), m.p. 80°; a mixture with authentic naphthalene melted at 80° and was not depressed. The residue (0.8 g) (after distilling off the naphthalene) was 2-phenylselenophene — white lustrous plates; m.p. 38° (from alcohol).

Found %: C 58.51, 58.58; H 4.21, 4.16. $C_{10}H_8Se$.

Calculated %: C 57.98; H 3.86.

On distilling the liquid hydrocarbon part of the catalyzate on a column of 35 theoretical plates efficiency, we isolated 2 g of benzene (b.p. 80°, n_D^{20} 1.5017, d_4^{20} 0.8803), 3 g of toluene, (b.p. 108.5° at 742 mm, n_D^{20} 1.4961, d_4^{20} 0.8666), which was oxidized to give 2 g of benzoic acid with m.p. 122° (mixed melting point with authentic benzoic acid was not depressed) and 7 g of unchanged 1-phenylbutene-3 (b.p. 105° at 105 mm, n_D^{20} 1.5065, d_4^{20} 0.8907).

3-Phenylselenophene. 26.4 g of 2-phenylbutene-2 (b. p. 72° at 12 mm, n_D^{20} 1.5370, d_4^{20} 0.9130) was reacted with 22 g of selenium dioxide. In all, 7 experiments were carried out (184.8 g of hydrocarbon and 154 g of selenium dioxide), and we obtained 151 g of catalyzate. The catalyzate was distilled in vacuum and first 127 g of hydrocarbon distilled off in the range 87-115° (95 mm). The residue in the flask crystallized; on steam distilling it we obtained 26 g of 3-phenylselenophene (12.5%), which consisted of well-formed, colorless plates: m. p. 97° (from alcohol).

Found %: C 58.13, 57.96; H 4.05, 4.08. $C_{10}H_8Se$.

Calculated %: C 57.98; H 3.86.

On distilling the hydrocarbon part on a column of 35 theoretical plates, we isolated a series of fractions, whose boiling points and refractive indices are given in Table 1.

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* We consider it our duty to thank the optical laboratory of the Institute of Heteroorganic Compounds of the Academy of Sciences USSR for plotting the absorption spectra of the arylselenophenes prepared in this work.

TABLE 1

Fraction No.	Boiling point (754 mm)	n_D^{20}	Amount (in g)	Fraction No.	Boiling point (754 mm)	n_D^{20}	Amount (in g)
I	To 134°	1.4962	9.0	VII	163—170°	1.4987	11.8
II	134—136	1.4960	5.0	VIII	170—173	1.5050	26.6
III	136—142	1.4947	1.0	IX	173—187	1.5130	35.2
IV	142—152	1.4947	4.0	X	187—193	1.5375	13.8
V	152—159	1.4955	5.6	Residue	—	—	1.7
VI	159—163	1.4960	12.6				

TABLE 2

Fraction No.	Combination scattering spectra of hydrocarbon fractions, obtained together with 3-phenylselenophene
I	221(2v);* 318(0.3, v); 413(0); 460(0.5); 494(1); 521(1.8); 537(1.2); **609**(0.2); 621(5); 726(0); 780(1.7); 769(2.5); 787(4); 845(1); 872(0); 967(0.5); **994**(6); **1002**(60); **1036**(12); 1105(1.5); **1156**(2.5); 1180(1.5); 1204(6, v); 1234(0); 1282—1296(1.5, v); 1382(1.5); 1442—1463(1.5, v); 1493(0.5); 1589(1); 1606(10); 1628(0.7)
II	232(0, v); 397(0); 459(0); 489(2.5); 556(0.5); 612(0); 621(5); 746(2); **769**(10); 845(1.5); 907(1.5); **1004**(50); 1031(12); 1065(0.5); 1102(0.5); 1160(2); 1179(0.8); **1203**(10); 1293(1.5, v) 1327(0.5, v) 1380(0.5); 1440—1463(1.5, v); 1545(0.5); 1585(1); **1605**(10); 1628(0.5)
IV	242(0.5, v); 260(0.5); 276(0.5); 318(1, v); 409(1); 456(1.5); 494(0); 518(0.5); 556(1); **619**(4); 734(3); 769(1); 815(1); 833—850(1.5, v); 901(1); **1001**(25); **1033**(9); 1093(2, v); 1160(2.5); 1186(1.5); **1204**(4); 1296(3.5, v); 1354(0.5) 1443—1460(3.5, v); 1545(0.5); 1580(1); 1602(10); 1628(0.5); 1660(1)
VI	249(1, v); 312(1, v); 333(0); 357(0); 387—397(0, v); 460(1.5); 492(0.5); 567(1); **621**(7); 716(0.1); **744**(6); 769(2); 821(0.1); 845(1); 888—905(1—2, v); 973(0.5); **1001**(30); **1037**(12); 1056(0); 1104(2, v) 1165(2.5); 1189(1.5); 1204(3.5); 1219(3.5); 1296(3, v); 1342(0.1); 1380(0.5); 1440—1460(2.5, v); 1545(0.3); 1585(1); 1605(10); 1632(1.5)
VIII	260(0.5); 333(0.5); 459(0.3); 562(0.5); **621**(4); 725(0.1); 734(3); 769(0.5); 845(1); 862(1); 897(1.5); **1001**(25); **1037**(9); 1107—1117(1.5, v); 1160(2.5); 1189(1.2); **1204**(3); 1267(1.5, v) 1295(1.5, v); 1354(1); 1382(0.5); 1442(3); 1493(0.5); 1545(1); **1602**(10); **1628**(1); 1652(3.5)
X	276(0.5); 329(0.5, v); 373(0.8, v); 417—421(0.5, v); 459(0.3); 518(0.1); 556(1); **621**(3); 734(3.5); 745(3.5); 769(0.1); 808(0); 840(3); 904(1); **1001**(25); **1030**(4); 1117(2.5); 1159(2.5); 1183(1, v); 1204—1219(1.5, v); 1247(0.5); 1285(6); 1356(1) 1380(2.5); 1406(0.1); 1440(1); 1460(2); 1545(1); 1578(0.1); **1603**(10; v); **1652**(10)

The composition of the fractions (I, II, IV, VIII and X) were investigated by combination light scattering. The method, apparatus, and materials used in the present work were similar to those described previously [8]. The combination scattering spectra (frequency range 200-1700 cm^{-1}) of the fractions investigated are given in Table 2.

The data given in Table 2, taking the most intense lines (separated), indicate that fraction I contained benzene [609 (0.2); 994 (6)] and toluene [1002 (60); 1036 (12); 1156 (2.5)]; fraction II — ethylbenzene [769 (10); 1004 (50); 1203 (10); 1605 (10)]; fraction IV — isopropylbenzene [619 (4); 1001 (25); 1033 (9); 1204 (4)]; fraction VI — n-propylbenzene [621 (7); 744 (6); 1037 (12)]; fraction VIII — α-methylstyrene [1001 (25); 1267 (1.5); 1602 (10); 1628 (1)]; isopropylbenzene [621 (4); 1001 (25); 1037 (9); 1204 (3)], and, possibly, n-propylbenzene [621 (4); 1037 (9)]; fraction X — 2-phenylbutene-2 [621 (3); 734 (3.5); 1001 (25); 1030 (4); 1603 (10); 1652 (10)].

3-p-Tolylselenophene. 29.2 g of 2-p-tolylbutene-2 (b.p. 86° at 6 mm, n_D^{20} 1.5342, d_4^{20} 0.9148) was reacted with 22 g of selenium dioxide. In all 3 experiments were carried out (87.6 g of hydrocarbon and 66 g of selenium dioxide), and we obtained 52 g of catalyzate, from which we distilled off 43.9 g of a hydrocarbon fraction in the range 120-140° (100 mm). The residue in the flask crystallized; on steam distilling it we obtained 12 g of 3-p-tolylselenophene (9.5%), which consisted of well-formed, white plates; m. p. 113° (from alcohol).

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* Transliterated from Russian — Publisher's note.

Found %: C 59.42, 59.49; H 4.81, 4.80. $C_{11}H_{10}Se$.

Calculated %: C 59.74, H 4.56.

In distilling the hydrocarbon part of the catalyzate on a column of 35 theoretical plates efficiency, we isolated the fractions given in Table 3.

In Table 4 the combination scattering spectra of fractions I, III and V are given.

TABLE 3

Fraction No.	Boiling point (757 mm)	n_D^{20}	Amt. (in g)	Fraction No.	Boiling point (757 mm)	n_D^{20}	Amt. (in g)
I	100—135°	1.4970	6.5	V	190—195°	1.5175	15
II	135—172	1.4970	2.3	VI	210—212	1.5255	10.2
III	172—180	1.4990	5.2	VII	95 (10 мм)	1.5350	4.5
IV	180—190	1.5040	2.3	Residue	—	—	1.2

TABLE 4

Fraction No.	Combination scattering spectra of hydrocarbon fractions obtained together with 3-p-tolylselenophene
I	221(1, b); 318(0.3, b); 413(0); 460(0.5); 494(1); 521(1.8); 557(1.2); **609**(0.2); 621(5); 726(0); 740(1.7); **769**(2.5); 787(4); 845(1); 872(0); 967(0.5); **994**(6); **1002**(60); **1036**(12); 1105(1.5); **1156**(2.5); 1180(1.5); **1204**(6, b); 1234(0); 1382(1.5); 1442(1.5, b); 1463(1.5, b); 1490(0.5); 1463(1.5, b); 1589(1); **1606**(10); 1628(0.7)
III	**221**(0.8, b); 257(1); 307(1); 373(0.5); **460**(1.5); 484(0.2); 530(0); 556(0); 585(1); 621(0); **645**(3.5); 695(0.3); 725(0.5); **805**(5); **822**(4.5); 859(0.3); 955(0.5); 1002(1.5); 1022(0.5); 1056(1); 1102(1, d); 1149(1); 1183(2); 1204(8); 1270(0, b); 1323(0); 1380(2); 1440(2, b); 1505(0.5); **1615**(10); 1650(1)
V	257(0.6, b); 314(0.5); **373**(0.5); 408(0.8); **460**(0.7); 494(0); 514(0.5); 518(0); 547(0); 586(0.5); 621(1); **645**(2); 671(0); 695(0); 734(1.5); 769(0); **800**(3, b); 822(1.5, b); 904(0.5); 937(0.5); **1002**(8); 1026(2); 1056(0.6, d); 1104(1); 1117(8); 1151(1.5); 1183(2); 1204(3); 1241(0.5); **1267**(6, b); 1380(3); 1440(2.5, b); 1493(0.6, bg); 1518(1); 1545(1, b); **1596—1614**(10, d, bg); **1652**(10)

Note: b = broad; d = doublet; bg = background.

Taking the most intense lines, it was established that fraction I contained benzene [609 (0.2); 994 (6)]; toluene [1002 (60); 1036 (12); 1156 (2.5)]; ethylbenzene [769 (2.5); 1002 (60); 1204 (6, broad); 1606 (10)]; fraction III — 1,4-methylethylbenzene [221 (0.8, broad)] 373 (0.5); 460 (1.5); 645 (3.5); 805 (5); 822 (4.5); 1615 (10)]; fraction V — 1,4-methylethylbenzene [373 (0.5); 460 (0.7); 645 (2); 800

After a second fractionation of fractions VI and VII, we obtained 5 g of unchanged 2-p-tolylbutene-2; b.p. 82° (9mm), n_D^{20} 1.5339.

2,3-Benzoselenophene. 21 g of styrene (b. p. 146°, n_D^{20} 1.5462, d_4^{20} 0.9073) was reacted with 22 g of selenium dioxide. In all, we carried out 6 experiments (126 g of hydrocarbon and 132 g of selenium dioxide) and obtained 102 g of catalyzate. After distilling off the hydrocarbon fraction in the range 53-63° (85 mm), the solid residue was steam distilled to give 12 g of 2,3-benzoselenophene (8%) as white crystals; m. p. 40° (from alcohol).

Found %: C 53.68, 53.72; H 3.55, 3.55. C_8H_6Se.

Calculated %: C 53.15; H 3.32.

The hydrocarbon part of the catalyzate was distilled on the column mentioned above, and as a result we obtained 28 g of ethylbenzene (b. p. 136° at 753 mm, n_D^{20} 1.4960, d_4^{20} 0.8669) and 35 g of unchanged styrene (b. p. 146° at 757 mm, d_4^{20} 0.9088, n_D^{20} 1.5461).

Preparation of arylselenophenes by treating arylalkenes with selenium.

3-Phenylselenophene. 26.4 g (0.2 mole) of 2-phenylbutene-2 was passed in a stream of nitrogen through a tube filled with pieces of porous porcelain mixed with 7 g of finely powdered selenium and heated to 500°; the hydrocarbon was introduced at 0.22 ml/min. In all, 6 experiments were carried out (158.4 g of hydrocarbon; 42 g of selenium), and 128 g of catalyzate obtained. The catalyzate was washed with alkali and, after drying with fused soidum hydroxide, distilled to give a hydrocarbon fraction (79.7 g) with b. p. 100-120° (100 mm); on steam distilling the solid residue, we obtained 36.0 g of 3-phenylselenophene (30%) with m. p. 97°; a mixed melting point with the 3-phenylselenophene,obtained in the previous series of experiments, was not depressed; m. p. 97°.

On distilling the hydrocarbon part of the catalyzate on a column, we obtained 70 g of unchanged 2-phenylbutene-2; b. p. 189° (753 mm), n_D^{20} 1.5370, d_4^{20} 0.9138.

3-p-Tolylselenophene 27 g (0.2 mole)of 2-p-tolylbutene-2 was reacted with 7 g of powdered selenium, as described above. In all, we carried out 3 experiments (87 g of hydrocarbon and 21 g of selenium), and obtained 80 g of catalyzate. After working up the catalyzate appropriately and distilling off the hydrocarbon part of it (76 g) in vacuum, b. p. 72-105° (10 mm), the solid residue was steam distilled to give 4.8 g of 3-p-tolylselenophene (10%); m. p. 113°. A mixed melting point with the 3-p-tolylselenophene obtained in the previous series of experiments was not depressed; m. p. 113°.

On fractionating the hydrocarbon part of the catalyzate on a column, we isolated 62 g of unchanged 2-p-tolylbutene-2; b. p. 95° (10 mm), n_D^{20} 1.5341, d_4^{20} 0.9148.

Acylation of arylselenophenes with silicoacetic anhydride.

2-Acetyl-3-phenylselenophene. With cooling and stirring, 4 g (0.015 mole) of anhydrous stannous chloride was added to the silicoacetic anhydride, prepared from 3.6 g (0.006 mole) of glacial acetic acid and 5 g (0.03 mole) of silicon tetrachloride in 36 ml of anhydrous benzene, followed by a solution of 6 g (0.03 mole) of 3-phenylselenophene in 15 ml of anhydrous benzene. After working up the reaction mixture suitably and distilling the reaction product, we obtained 2 g (27%) of 2-acetyl-3-phenylselenophene.

B. p. 173-174° (5 mm), n_D^{20} 1.6420, d_4^{20} 1.3950, MR_D 61.4. $C_{12}H_{10}OSeF_5$.

Calculated MR_D: 61.5.

Found %: C 57.45, 57.61; H 3.34, 3.61. $C_{12}H_{10}OSe$.

Calculated %: C 57.83; H 4.01.

2,4-Dinitrophenylhydrazone of 2-acetyl-3-phenylselenophene: m. p. 157-158° (from alcohol).

Found %: N 12.82, 12.68. $C_{18}H_{14}O_4N_4Se$.

Calculated %: N 13.05.

2-Acetyl-3-p-tolylselenophene. 3.6 g (0.006 mole) of glacial acetic acid, 5 g (0.03 mole) of silicon tetrachloride, 4 g (0.015 mole) of anhydrous stannic chloride, and 6.8 g (0.03 mole) of 3-p-tolylselenophene were used in the reaction. We obtained 2.4 g (31%) of 2-acetyl-3-p-tolylselenophene.

B. P. 179-180° (5 mm), n_D^{20} 1.6370, d_4^{20} 1.4603, MR_D 67.72. $C_{13}H_{12}OSeF_5$.

Calculated: 66.11.

Found %: C 59.06, 59.26; H 4.20, 4.37. $C_{13}H_{12}OSe$.

Calculated %: C 59.32; H 4.56.

2,4-Dinitrophenylhydrazone of 2-acetyl-3-p-tolylselenophene; m. p. 176-177° (from alcohol).

Found %: N 12.53, 12.40. $C_{19}H_{16}O_4N_4Se$.

Calculated %: N 12.64.

2-Acetyl-4,5-benzoselenophene. 4.6 g of glacial acetic acid, 6.42 g of silicon tetrachloride, 5.2 g of anhydrous stannic chloride, and 7 g of benzoselenophene were used in the reaction. We obtained 3.2 g (69%) of 2-acetyl-4,5-benzoselenophene; m. p. 81° (from dilute alcohol).

Found %: C 53.73, 53.85; H 4.01, 4.00. $C_{10}H_8OSe$.

Calculated %: C 53.82; H 3.58.

2,4-Dinitrophenylhydrazone of 2-acetyl-4,5-benzoselenophene; m. p. 261° (from pyridine).

Found %: N 13.75, 13.70. $C_{16}H_{12}O_4N_4Se$.

Calculated %: N 13.89.

SUMMARY

1. The reaction of arylalkenes – 2-phenylbutene-2,2-p-tolylbutene-2, and also styrene – with selenium dioxide in the presence of chromic oxide on aluminum oxide at 450° resulted in the formation of 3-phenylselenophene, 3-p-tolylselenophene, and 2,3-benzoselenophene, respectively.

2. The reaction of 2-phenylbutene-2 and 3-p-tolylbutene-2 with selenium at 500° also resulted in the formation of 3-phenylselenophene and 3-p-tolylselenophene, respectively.

3. Acylation of the above 3-arylselenophenes and 2,3-benzoselenophene with silicoacetic anhydride resulted in 2-acetyl-3-phenylselenophene, 2-acetyl-3-p-tolylselenophene, and 2-acetyl-4,5-benzoselenophene, respectively.

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SOME CHARACTERISTICS OF N-BENZYLATED PEPTIDES. II.

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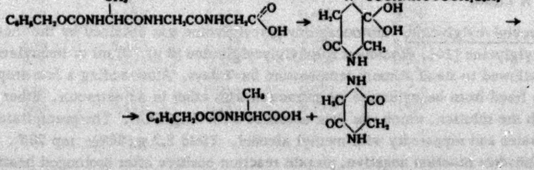
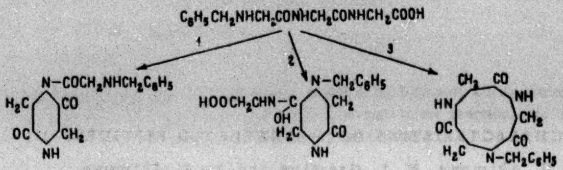
In 1954 a paper was published describing the preparation of diketopiperazines from polypeptides [1]. Their formation was explained by the authors as the result of the elimination of pairs of amino acids from either the carboxylic or amino ends of the polypeptides. It was suggested that, if cyclization occurred with the carboxylic end, then diketopiperazines ought to be formed even after substitution of the amino group in the peptide. This hypothesis was confirmed for two hexapeptides. Diketopiperazines were produced by heating carbobenzyloxyalanylglycylglycylalanylglycylglycine and carbobenzyloxyglycylglycylalanylglycylglycylalanine, or their methyl esters [2], with diethylformamide at 110° in the presence of tributylamine. The results showed that diketopiperazines could be formed with a free carboxylic end to the peptide, and that the presence of an ester group was not essential to cyclization. It was also found [3] that reduction of a carbobenzyloxy peptide in xylene, by bubbling hydrogen through the hot solution, gave a theoretical yield of the diketopiperazine. When the above treatment was applied to carbobenzyloxy-tripeptides the products were neither cyclic tripeptides nor tripeptides, but were believed to be derivatives of diketopiperazine amino acids.

On the basis of our own work [4-7] on synthesis of compounds with the N-aminoacyl type of linkage, and also from a relative survey of the liberation of N-aminoacyldiketopiperazines from proteins, the following mechanism is suggested for the formation of diketopiperazines from peptides with a substituted amino group.



In the present paper we investigated the behavior of benzyl substituted tripeptides. We showed previously [8] that on heating N-benzyl-dipeptides with nitrobenzene or glycol, according to their amino acid composition, they were converted quantitatively to N-benzyl-diketopiperazines. The formation of these shows that the benzyl group has a special influence on the other functional groups of the system, and, in particular, increases the carbonyl function of the terminal carboxyl group. The cyclization reaction in nitrobenzene can be considered as a simple condensation of the carboxylic carbonyl group with the hydrogen of the benzyl substituted amino group. Cyclization in glycol is also the result of condensation, but differs in that it is accompanied by the elimination of alcohol (for an ester may be formed as an intermediate product during cyclization by heating in glycol). In this connection it was extremely important to investigate cyclization tendencies with N-benzyl-tripeptides. This latter can procede in three different direction to form N-benzylaminoacyl-diketopiperazines, asymmetric amidines, or N-benzyl-cyclotripeptides according to the following scheme.



By varying the position of the benzyl groups in the tripeptide molecule it should be possible to control the nature of the cyclization reaction. For instance, with two benzyl groups instead of one the third product should be excluded. On the contrary, if the benzyl group is introduced into an —NH—CO— grouping, the only product of cyclization should be the cyclotripeptide.

To investigate this the following compounds were synthetized — N,N'-dibenzylglycylglycylglycine, N-benzylleucylglycylglycine, N-benzylglycylalanylphenylalanine, and N-benzylleucylalanylphenylalanine — and their cyclization behavior was studied.

EXPERIMENTAL

I. Synthesis of N-benzyl-tripeptides.

1. N,N'-Dibenzylglycylglycylglycine. Diketopiperazine (1.14 g) was hydrolyzed to the dipeptide by standing for 20 minutes with 10 ml of 1 N NaOH. The resulting solution of the dipeptide was cooled and the chloranhydride [9] of the dibenzylglycocoll was added, a little at a time, with vigorous stirring. At the end of the reaction (pH 7) the solution was evaporated to dryness. The product was recrystallized from alcohol by precipitation with ether. M. p. 245° (decomp.). Soluble in alcohol, insoluble in water, Positive biuret reaction (Table).

Found %: N 11.13. $C_{20}H_{23}O_4N_3$.

Calculated %: N 11.09.

2. N-Benzylleucylglycylglycine. Bromocapronylglycylglycine was obtained by the method given for bromoisocapronylglycylglycine [10]. Bromonorcapronylglycylglycine (3 g), 10 ml of benzylamine, and 25 ml of water were allowed to stand at room temperature for 7 days. After adding a few drops of 4% NaOH, the clear solution was freed from benzylamine by extraction with ether in an extractor. Ether was removed by blowing air through the solution, which was then acidified with CH_3COOH. The precipitate was filtered off and washed with water and repeatedly with methyl alcohol. Yield 2.2 g (56%); mp 235°. Insoluble in water or alcohols. Ninhydrin reaction negative, picrate reaction positive after prolonged heating, biuret reaction positive (Table).

Found %: C 60.55; H 7.57; N 12.65; amino nitrogen (Willstatter) 4.20. $C_{17}H_{25}O_4N_3$.

Calculated %: C 60.88; H 7.51; N 12.53; amino nitrogen 4.17.

3. N-Benzylglycylalanylphenylalanine. Chloracetylalanylphenylalanine (2.5 g) was allowed to stand at room temperature with a fivefold excess of benzylamine and 20 ml of water for 24 hours. The precipitate formed was filtered off and washed several times with water. Yield 4.75 g (86%); mp 221-222°. Insoluble in water, feebly soluble in alcohol. Ninhydrin reaction negative, biuret reaction positive (Table). The amino acid composition was determined by paper chromatography of the hydrolyzate, using a mixture of butanol, water and acetic acid (in the ratio 5:4:1).

Found %: C 64.15; H 6.66; N 10.58; amino nitrogen (Willstatter) 3.49. $C_{21}H_{25}O_4N_3\cdot\frac{1}{2}H_2O$.

Calculated %: C 64.27; H 6.68; N 10.71; amino nitrogen 3.57.

On drying the substance in vacuo over P_2O_5 there was a loss of $\frac{1}{2}H_2O$.

Found %: C 65.98; H 6.68; N 10.87. $C_{21}H_{25}O_4N_3$.

Calculated %: C 65.78; H 6.57; N 10.96.

4. N-Benzylleucylalanylphenylalanine. Bromocapronylalanylphenylalanine [10] (2 g) was allowed to stand with 10 ml of benzylamine for 5 days at room temperature. Excess benzylamine was extracted with ether. After two hours extraction spontaneous crystallization occurred in the extractor. The deposit was filtered off and washed with water and then with acetone. Melting point 214°. Yield 61%. The ethereal solution from the extractor gave a tripeptide biuret reaction on shaking with a copper salt and NaOH. The ethereal solution, after concentration, was treated twice with 4% NaOH in a separating funnel. The alkaline solution was freed from ether by blowing air through it and acidified with CH_3COOH. The resulting precipitate was filtered off and washed several times with water, until it gave a negative reaction for halide, and then with acetone. Melting point 214°. Insoluble in water or acetone. Soluble in alcohols. Ninhydrin reaction negative, picrate and biuret reactions positive (Table).

Found %: C 67.00; H 7.64; N 9.14; amino nitrogen (Willstatter) 3.14. $C_{25}H_{33}O_4N_3 \cdot \frac{1}{2}H_2O$.

Calculated %: C 66.93; H 7.64; N 9.37; amino nitrogen 3.12.

Spectrophotometric Data on Solutions of the Copper Biuret Complexes of N-benzyl-tripeptides.

Wave length λ (in mμ)	Optical density ε of 0.27% solution of copper biuret complex			
	N,N'-dibenzyl glycylglycylglycine	N-benzyl leucylglycylglycine.	N-benzyl glycylalanylphenylalanine	N-benzyl leucylalanylphenylalanine
500	0.180	0.443	0.450	0.395
510	0.198	0.517	0.502	0.414
520	0.230	0.561	0.538	0.439
530	0.287	0.603	0.570	0.473
540	0.327	0.623	**0.581**	**0.478**
550	0.365	**0.629**	**0.581**	**0.478**
560	0.405	0.616	0.570	0.462
570	0.473	0.588	0.535	0.450
580	0.518	0.548	0.322	0.415
590	0.569	0.498	0.472	0.391
600	0.601	0.442	0.428	0.360
610	0,628	0.395	0.390	0.327
620	**0.633**	0.342	0.338	0.295
630	0.623	0.303	0.298	0.265
640	0.599	0.264	0.253	0.238
650	0.552	0.234	0.227	0.216
660	0.493	0.217	0.213	0.204

II. Cyclization of N-benzyl-tripeptides.

1. N,N'-Dibenzylglycylglycylglycine. a) In nitrobenzene. Dibenzylglycylglycylglycine (0.1 g) was heated to boiling with 15 times the quantity of nitrobenzene. The material did not dissolve, but suffered a change. The strongly colored product was dissolved in water, filtered free of the insoluble part (found by its properties to be dibenzylglycocoll), decolorized with charcoal, and precipitated with acetone. The precipitate was filtered off. Mp 300° (decomp.). Thus the product was shown to be diketopiperazine.

Found %: N 24.78. $C_4H_6O_2N_2$.

Calculated %: N 24.56.

b) In glycol. The same result was obtained when the nitrobenzene was replaced by glycol. The products were dibenzylglycocoll (mp 200°) and diketopiperazine.

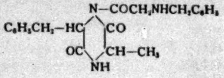
Found %: N 24.46. $C_4H_6O_2N_2$.

Calculated %: N 24.56.

A paper chromatogram of this material, using a butanol — water — acetic acid medium, on development with benzidine gave a single spot corresponding to diketopiperazine. Thus the products of cyclization of dibenzylglycylglycylglycine were identified as dibenzylglycocoll and diketopiperazine.

2. N-Benzylglycyl-(alanylphenylalanyl)-anhydride from N-benzyl-glycylalanylphenylalanine. N-benzylglycylalanylphenylalanine (0.5 g) of mp 221° was heated in an oil bath at 221-226° (not above) for 2.5 hours. The melt (together with the test tube) was dried over H_2SO_4 in a vacuum desiccator, the product was dissolved with warming in the minimum quantity of absolute alcohol, and anhydrous ether was added until crystallization began. The white crystalline material, which formed on standing, was filtered off and washed with anhydrous ether. This was recrystallized from alcohol by precipitation with ether. Yield 0.3 g (60%); mp 230°. On electrophoresis the material was electrically neutral in 30% CH_3COOH, but moved slightly to the anode in pyridine. On paper chromatography (solvent water — acetic acid — butanol) the unhydrolyzed compound showed a single spot on development with benzidine. $R_f = 0.90$. Chromatography of the hydrolyzate (36 hours) showed glycocoll, alanine, and phenylalanine.

Properties of the material: readily soluble in alcohols, acetone and chloroform; insoluble in alkali. Picrate reaction positive, biuret reaction negative. Reaction with hydrazine in absolute alcohol and precipitation of the product with anhydrous ether, followed by recrystallization from alcohol gave alanyl-phenylalanine anhydride. Paper chromatography of this material, using butanol-water-acetic acid as solvent, gave a single spot on development with benzidine, which identified it as alanylphenylalanine anhydride.



Found %: C 65.65, 65.43; H 6.54, 6.86. $C_{21}H_{25}O_4N_3$.

Calculated %: C 65.78; H 6.57; N 10.96.

3. Electro-reduction of N-benzylglycyl-(alanylphenylalanyl)-anhydride. The material (0.093 g) was dissolved in ethyl alcohol and reduced at a mercury cathode of surface area 97 sq cm (total volume of mercury in cathode 70 ml; 50-100 ml of 5% hydrochloric acid) for 7 hours at 15°. After reduction the solution was evaporated to dryness on a water bath at 5 mm, and the residue was taken up in 50% alcohol and made up to 50 ml in a graduated flask; 25 ml of this solution was freed from alcohol and hydrolyzed with 20 ml of 25% hydrochloric acid for 10 hours. Chromatography and development with ninhydrin gave a deep yellow piperazine spot and a lilac-red benzylglycocoll spot. The chromatogram also showed traces of glycocoll, alanine, and phenylalanine.

These chromatographic results showed that electro-reduction led to the formation of a piperazide, indicating the presence in the material of a diketopiperazine nucleus. Further investigation of the structure is in hand.

4. N-Benzylleucyl-(alanylphenylalanyl)-anhydride from benzylleucylalanylphenylalanine. N-benzyl-leucylalanylphenylalanine (0.5 g) was heated in a test tube in an air bath to 225°. The melt was held at this temperature for 2.5 hours. It was then dissolved in absolute alcohol and precipitated with ether. The product was filtered off. Mp 238°. The material was soluble in alcohol, acetone, and chloroform, insoluble in water or alkali. The picrate reaction was positive without heating; the biuret reaction was negative, and there was no tripeptide reaction after hydrolysis with 4% NaOH. Paper chromatography of the acidified hydrolyzate (36 hours), using butanol-water-acetic acid as solvent, showed the presence of three amino acids, alanine, phenylalanine, and leucine. Chromatography of the unhydrolyzed material showed one spot with $R_f = 0.94$.

Found %: C 71.13; H 7.56; N 9.81. $C_{25}N_{31}O_3N_3$.

Calculated %: C 71.22; H 7.41; N 9.97. By Willstatter's method, not by titration.

5. Electro-reduction of N-benzylleucyl-(alanylphenylalanyl)-anhydride was carried out as previously described for N-benzylglycyl-(alanylphenylalanyl)-anhydride. Hydrolysis of the electrically reduced material (52 hours) and precipitation with picric acid gave the dipicrate of 2-methyl-5-benzyl piperazine, whose melting point coincided with that of the dipicrate of the same piperazine, obtained by the electro-reduction of alanylphenylalanine anhydride.

a) Electro-reduction. Alanylphenylalanine anhydride (0.2270 g) was dissolved in 50 ml of glacial acetic acid and, after adding 30 ml of 10% hydrochloric acid, was reduced electrically at a mercury cathode for 6.5 hours. The solution was then separated from the mercury and evaporated to dryness in vacuo. The dry residue was dissolved in a small quantity of water and treated with a saturated aqueous solution of picric acid until no more precipitate formed. The precipitate was filtered off and purified by recrystallization from hot water. The precipitate formed on cooling was washed several times with water, once with alcohol, and several times with ether. Mp 285° (decomp.). A chromatogram of this material (solvent butanol-water-acetic acid) showed a single spot after development with benzidine. This proved that the picrate of 2-methyl-5-benzyl-piperazine was homogeneous. It dissolved in acetic and formic acids on warming.

Found %: C 44.36; H 3.87; N 17.18. $C_{24}H_{24}O_{14}N_8$.

Calculated %: C 44.44; H 3.73; N 17.29.

SUMMARY

1. N,N'-dibenzylglycylglycylglycine, N-benzylleucylglycylglycine, N-benzylglycylalanylphenyl-alanine and N-benzylleucylalanylphenylalanine have been synthesized.

2. The cyclization of these N-benzyl-tripeptides has been investigated. It has been found that, under the conditions of cyclization, N,N'-dibenzylglycylglycylglycine splits up to form dibenzylglycocoll and diketopiperazine. Two other tripeptides – N-benzyl-glycylglycylalanylphenylalanine and N-benzyl-leucylalanylphenylalanine – cyclize to form N-aminoacyl-diketopiperazines.

3. The structures of the N-benzylglycyl-(alanylphenylalanyl)- and N-benzylleucyl-(alanylphenyl-alanyl)-anhydrides obtained have been established by elementary analysis, chromatography, electro-reduction, and reactions with hydrazine.

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* Original Russian pagination. See C. B. translation.

FLUORINE DERIVATIVES OF ACENAPHTHENE. I.

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Fluorine derivatives of acenaphthene have not been investigated previously. The only one known is perfluorodecahydroacenaphthene, obtained by fluorinating acenaphthene with silver difluoride [1]. An attempt to fluorinate acenaphthene with p-tolyl iodide difluoride did not succeed [2].

There is information in the literature on the use of acenaphthene derivatives as insecticides and as physiologically active substances [3]. So that it is of interest to investigate fluorine derivatives from this point of view.

We have prepared 2-, 3- and 4-fluoro acenaphthene from the corresponding amines, using Schiemann's diazonium borofluoride method.

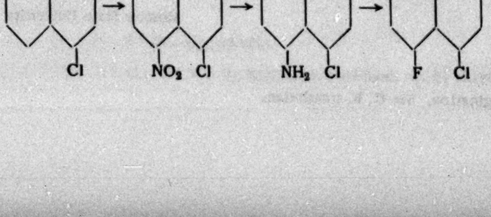
The fluoroacenaphthenes were found to be white crystalline materials. The 2- and 4-fluoroacenaphthenes had melting points above those of the corresponding other halogen derivatives (see Table).

Substituent	Melting point of the specified substituted derivative.		
	2	3	4
H	95°		
F	95-96	57-58°	94-95°
Cl	76-77 [4]	Oil [5]	70 [6]
Br	78 [4]		52 [7]
I	87 [4]	88-90 [4]	63 [7]

This rule did not apply to 3-fluoroacenaphthene. It can be seen from the Table that acenaphthene and 2- and 4-fluoroacenaphthenes have similar melting points. Addition of acenaphthene depressed the melting point of 2- and 4-fluoroacenaphthenes; but the 2- and 4-fluoroacenaphthenes did not depress each other's melting points.

2-Fluoroacenaphthene could be oxidized to the naphthalic acid under considerably milder conditions than 4-fluoroacenaphthene.

Chlorination of 4-fluoroacenaphthene with sulfuryl chloride gave 4-chlor-5-fluoroacenaphthene in 58% yield. The structure of the latter was established by synthesis according to the following scheme.



EXPERIMENTAL

4-Aminoacenaphthene was obtained from 4-nitroacenaphthene by reduction with sodium hydrosulphite in aqueous alcohol [8].

4-Fluoracenaphthene. A mixture of 45 g of 4-aminoacenaphthene in 81 ml of concentrated hydrochloric acid and 680 ml of water was cooled to 0°, and a solution of 18.9 g of sodium nitrite in 45 ml of water was added slowly with stirring. There was considerable foaming during the diazotization, and the solution turned a dark green color. The reaction mixture was stirred at 0° for 30 minutes, treated with hydro-fluoboric acid obtained from 33.4 g of boric acid and 107.5 g of 40% hydrofluoric acid, and allowed to stand at −5° for 30 minutes. The dark green precipitate of the diazonium borofluoride was filtered off, washed with cold methyl alcohol, and then with ether, and dried in a vacuum desiccator over calcium chloride. Yield of borofluoride 64.7 g (85%). Mp 122-123°. After decomposition of the dry diazonium salt the fluoroacenaphthene was distilled in steam. Yield 17.29 g (37.8%). Colorless prisms from alcohol. Mp 94-95°.

Found %: F 11.07, 11.03. $C_{12}H_9F$.

Calculated %: F 11.04.

The picrate, obtained by mixing alcoholic solutions of equimolecular quantities of fluoroacenaphthene and picric acid, was in the form of orange needles with a mp of 152-153°. It partly decomposed on recrystallization.

Found %: N 10.72, 10.61. $C_{18}H_{12}O_7N_3F$.

Calculated %: N 10.47.

2-Aminoacenaphthene was prepared by the method of Morgan and Harrison [4].

2-Fluoroacenaphthene. A solution of 1 g of sodium nitrite in 2 ml of water was added slowly with stirring to a mixture of 2.36 g of 2-aminoacenaphthene with 5 ml of concentrated hydrochloric acid and 25 ml of water, at a temperature between 0 and −5°. At the end of the diazotization there was added a cold (0°) solution of hydrofluoboric acid, prepared from 25 g of 40% hydrofluoric acid and 7.8 g of boric acid. The reaction mixture was stirred and strongly cooled for 30 minutes. The yellow diazonium borofluoride was filtered off and washed with methyl alcohol and with ether. The yield was 3.5 g (88.5%). The diazonium borofluoride was decomposed by heating, and the reaction product was steam distilled. Yield of fluoroacenaphthene 1.86 g (77%). Colorless needles from alcohol. Mp 95-96°.

Found %: F 11.22, 11.02. $C_{12}H_9F$.

Calculated %: F 11.04.

The picrate of 2-fluoroacenaphthene was in the form of orange needles of mp 137-138°. The melting point was lowered by recrystallization.

Found %: N 10.67, 10.65. $C_{18}H_{12}O_7N_3F$.

Calculated %: N 10.47.

3-Aminoacenaphthene was prepared by the method of Morgan and Stanley [5].

3-Fluoroacenaphthene. A solution of 0.29 g of sodium nitrite in 1 ml of water was added with stirring to a mixture of 0.7 g of 3-aminoacenaphthene with 1 ml of concentrated hydrochloric acid and 10 ml of water at 0°. There was added a hydrofluoboric acid solution, prepared from 2.17 g of boric acid and 7 g of 40% hydrofluoric acid. The preparation was continued as described above. Yield 0.12 g (16.8%). Colorless crystals from alcohol. Mp 57-58°.

Found %: F 11.18, 11.26. $C_{12}H_9F$.

Calculated %: F 11.04.

4-Fluoronaphthalic anhydride. Sodium dichromate (7.8 g) was added in portions, with vigorous stirring, to a solution of 1 g of 4-fluoroacenaphthene in 20 ml of glacial acetic acid, heated on a water bath. The reaction mixture was heated on a water bath for 1 hour, boiled on gauze for 2 hours, and diluted with water. The crystals obtained were filtered off and carefully washed free from chromium salts with hot water. The product was dissolved by heating on a water bath with 50 ml of 6% soda solution. The solution was filtered and acidified with sulfuric acid, and the resulting precipitate was crystallized from acetic acid and dried for 2 hours at 130-140°. Yield of 4-fluoronaphthalic anhydride 0.7 g (57%). Mp 220-221°.

Found %: F 8.65, 8.54. $C_{12}H_5O_3F$.

Calculated %: F 8.79.

The dimethyl ester of 4-fluoronaphthalic acid was obtained by methylation of 4-fluoronaphthalic acid with an alkaline solution of dimethyl sulfate. The product was recrystallized from aqueous methyl alcohol. Colorless shining plates. Mp 108-109°.

Found %: F 7.39, 7.53. $C_{14}H_{11}O_4F$.

Calculated %: F 7.25.

2-Fluoronaphthalic anhydride. Sodium dichromate (2 g) was added in portions, with vigorous stirring, to a solution of 0.5 g of 2-fluoroacenaphthene in 6 ml of glacial acetic acid, heated on a water bath. After further heating for 30 minutes the reaction mixture was diluted with water. The product was worked up as described above. The yield of anhydride was 0.29 g (46%) in the form of a yellow powder. Recrystallization from acetic acid gave pale yellow needles. Mp 264-265°.

Found %: F 8.54, 8.59. $C_{12}H_5O_3F$.

Calculated %: F 8.79.

When 2-fluoroacenaphthene was oxidized under the conditions described for 4-fluoroacenaphthene, a product was obtained which was readily soluble in water. Its structure has not been determined.

4-Chloro-5-fluoroacenaphthene. Powdered 4-fluoroacenaphthene (2 g) was treated with 1.5 ml of sulfuryl chloride. The reaction mixture liquefied and hardened in 1.5-2 hours. The next day the product was ground up with petroleum ether, filtered off, and washed with petroleum ether. Yield 1.4 g (58.3%). After two crystallizations from alcohol (with decolorization by charcoal) white shining needles were obtained of mp 125-126°.

Found %: F 8.95, 8.98. $C_{12}H_8ClF$.

Calculated %: F 9.21.

4-Chloroacenaphthene was prepared by chlorination of acenaphthene with sulfuryl chloride [6].

4-Chloro-5-nitroacenaphthene. A mixture of 7.5 ml of nitric acid (d 1.5) and 7.5 ml of glacial acetic acid was added, in the course of 30 minutes, to a solution of 9.42 g of chloroacenaphthene in 60 ml of glacial acetic acid at 10-15°. The reaction mixture was then held at 10° for 30 minutes. The nitro compound was filtered off and washed with a small quantity of glacial acetic acid and cold methyl alcohol. Two crystallizations from methyl alcohol gave 3.12 g (33.4%) of 4-chloro-5-nitroacenaphthene of mp 136-137°. The literature reference [9] gives — mp 136-138°, yield 10%.

4-Chloro-5-aminoacenaphthene. A solution of 18.9 g of stannous chloride in 16 ml of concentrated hydrochloric acid was added in portions, with stirring, to a mixture of 5.6 g of 4-chloro-5-nitroacenaphthene with 70 ml of methyl alcohol, heated on a water bath. In a few minutes the solution turned brick-red in color. The solution was boiled for 1 hour, the methyl alcohol was evaporated off, and the residue was treated with 30% alkali. The amine was filtered off, washed well with water, dissolved by heating with dilute hydrochloric acid, boiled with charcoal, filtered, and precipitated with ammonia. Crystallization from petroleum ether gave a yield of 2.32 g (47.5%), mp 143-144°. The literature [9] gives the mp as 145-146°.

The acetyl derivative had an mp of 185-186° (from aqueous alcohol).

Found %: N 5.72, 5.81. $C_{14}H_{12}NOCl$.

Calculated %: N 5.7.

4-Chloro-5-fluoroacenaphthene was synthetized by the method described for 4-fluoroacenaphthene. 4-Chloro-5-aminoacenaphthene (2 g) gave 2.3 g (64%) of the diazonium borofluoride. The decomposition temperature was 131-132°. After crystallization from ethyl alcohol the yield of 4-chloro-5-fluoroacenaph--thene was 0.26 g (12.7%). White needles of mp 124-126°. The product gave no depression when mixed with a sample of the material obtained by chlorinating 4-fluoroacenaphthene with sulfuryl chloride.

SUMMARY

With the object of investigating their insecticidal properties, the following compounds have been synthesized — 2-, 3- and 4-fluoroacenaphthenes, the anhydrides of 2- and 4-fluoronaphthalic acids, and 4-fluoro-5-chloroacenaphthene.

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SYNTHESIS OF SUBSTITUTED 1-BENZYL-3,4-DIHYDROISOQUINOLINES

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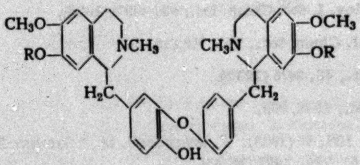
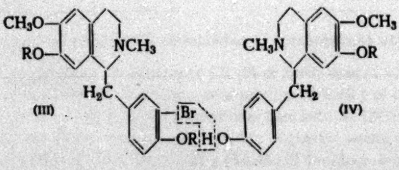
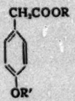
Examples of bisbenzylisoquinoline derivatives are provided by the biscoclaurine monoethers [1], which include the alkaloids magnolin (I), dauricine (II), magnolamine and aztequine* of varied physiological activity.


(I) $R = H$
(II) $R = CH_3$

One method of obtaining such compounds is by the interaction of two suitable halogen (III) and hydroxy (IV) derivatives of benzylisoquinoline with the formation of an oxygen bridge between the two phenyl groups.


(III) (IV)

In this work we have obtained some substituted phenylacetic acids and their esters (V-IX).



	(V)	(VI)	(VII)	(VIII)	(IX)
R	CH_3	H	CH_3	CH_3	H
R'	$COCH_3$	COC_6H_5	COC_6H_5	CH_2OCH_3	$COOCH_3$

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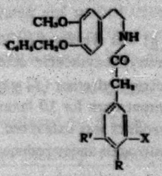
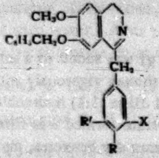
* Transliteration of Russian – Publisher's note.

β-(3-methoxy-4-benzyloxy)-phenylethyl amides (X-XV),



	(X)	(XI)	(XII)	(XIII)	(XIV)	(XV)
R	$OCOC_6H_5$	OCH_2OCH_3	$OCOOCH_3$	Cl	NO_2	OCH_3
R'	H	H	H	H	H	OCH_3
X	H	H	H	H	H	Br

and 1-benzyl-3,4-dihydroisoquinoline derivatives (XVI-XX),



	(XVI)	(XVII)	(XVIII)	(XIX)	(XX)
R	OCH_2OCH_3	NO_2	$OCOOCH_3$	OCH_3	OCH_3
R'	H	H	H	H	OCH_3
X	H	H	H	Br	Br

which can be used to build up the molecules of the alkaloid magnoline and its analogs.

It was shown that the interaction of β-(3-methoxy-4-benzyloxy)-phenylethylamine with the methyl ester of 4-acetoxyphenylacetic acid (V) at 110 and at 185-190° yielded β-(3-methoxy-4-benzyloxy)-phenylethylacetamide. A similar reaction occurred with the methyl ester of 4-benzoyloxyphenylacetic acid (VII), giving the corresponding benzamide.

A reacylation reaction was also observed in an attempted closure of the isoquinoline nucleus when the β-(3-methoxy-4-benzyloxy)-phenylethylamide of 4-benzoyloxyphenylacetic acid was treated with phosphorus oxychloride in boiling toluene. The hydrochloride of 1-phenyl-6-methoxy-7-benzyloxy-3,4-dihydroisoquinoline was obtained instead of the expected hydrochloride of 1-(4'-benzoyloxy)-benzyl-6-methoxy-7-benzyloxy-3,4-dihydroquinoline.

EXPERIMENTAL

Methyl ester of 4-acetoxyphenylacetic acid (V). The methyl ester of 4-hydroxyphenylacetic acid [2] (10 g), 150 ml of dry pyridine and 18.2 ml of acetic anhydride were heated together with stirring for 1 hour at 100°. The pyridine was evaporated off in vacuo. The residue was dissolved in ether and washed with dilute sulfuric acid and with 5% caustic soda. After evaporating off the solvent the ester was distilled in vacuo. Yield 8.8 g (70%). Bp 139-140° (4 mm).

Found %: C 63.61; H 5.93. $C_{11}H_{12}O_4$.

Calculated %: C 63.46; H 5.77.

4-Benzoyloxyphenylacetic acid (VI). 4-Hydroxyphenylacetic acid [3] (4 g) was added to 3 g of caustic potash dissolved in 12 ml of water. Then, with stirring and cooling (the reaction mixture was kept at 10-15°), 3.1 ml of benzoyl chloride and 3 g of caustic potash in 12 ml of water were added gradually. After standing for 1 hour the unreacted benzoyl chloride was extracted with ether, and the cooled solution was acidified with hydrochloric acid. Yield 61.5 g (92.4 %). Colorless crystals from methyl alcohol, mp 154-155°.

Found %: C 70.19, 70.28; H 4.61, 4.86. $C_{15}H_{12}O_4$.

Calculated %: C 70.31; H 4.69.

Methyl ester of 4-benzoyloxyphenylacetic acid (VII). Sodium (0.14 g) was dissolved in 10 ml of anhydrous ethyl alcohol and treated with 1 g of the methyl ester of 4-hydroxyphenylacetic acid in 3 ml of anhydrous alcohol. The solvent was removed in vacuo. The dry residue was suspended in 10 ml of dry benzene, and 0.7 ml of benzoyl chloride was added with continuous shaking. After standing for 1 hour any solid was filtered off, the solvent was evaporated off in vacuo, and the residue was distilled.

Found %: C 71.08, 71.23; H 5.20, 4.90. $C_{16}H_{14}O_4$.

Calculated %: C 71.11; H 5.19.

Methyl ester of 4-methoxymethoxyphenylacetic acid (VIII). Sodium (1.2 g) was dissolved in 30 ml of anhydrous methyl alcohol and treated with 8.3 g of the methyl ester of 4-hydroxyphenylacetic acid. The mixture was stirred and cooled with ice while 4 g of freshly distilled monochlorodimethyl ether [4] was added over a period of 5 hours. The reaction mixture was allowed to stand at room temperature for 10 hours. Any solid was filtered off, the methyl alcohol was evaporated off in vacuo, and the product was extracted with ether. After evaporating off the ether the material was distilled in a stream of nitrogen under reduced pressure. Yield 7 g (66.6%). Bp 120-123° (1 mm).

Found %: C 62.88; H 6.69. $C_{11}H_{14}O_4$.

Calculated %: C 62.86; H 6.66.

4-Carbomethoxyphenylacetic acid (IX). 4-Hydroxyphenylacetic acid (2.5 g) was added to a solution of 1.35 g of caustic soda in 35 ml of water. The mixture was cooled to 0-5° and shaken vigorously with 1.7 g of the methyl ester of chlorocarbonic acid. The solution was kept cold, and dilue (1:1) hydrochloric acid was added over a period of 10 minutes until the liquid was acid. The precipitate formed was filtered off and washed with water. Yield 2.78 g (82.7%). Colorless transparent crystals from dry benzene, mp 96-97°.

Found %: C 57.06, 56.95; H 4.67, 4.68. $C_{10}H_{10}O_5$.

Calculated %: C 57.14; H 4.76.

Reaction between β-(3-methoxy-4-benzyloxy)-phenylethylamine and the methyl ester of 4-acetoxy-phenylacetic acid. The methyl ester of 4-acetoxyphenylacetic acid (V) (1.04 g), 1.3 g of β-(3-methoxy-4-benzyloxy)-phenylethylamine [5] and 0.4 ml of dry pyridine were heated to 185-190° or to 110-115° in the presence of toluene. In both cases the product melted at 109-110°, corresponded in melting point and nitrogen content to 3-methoxy-4-benzyloxyphenylethylacetamide, and gave no depression with the latter in a mixed melting point determination.

Found %: N 4.84, 4.84. $C_{18}H_{21}O_3N$.

Calculated %: N 4.68.

Reaction between β-(3-methoxy-4-benzyloxy)-phenylethylamine and the methyl ester of 4-benzoyloxyphenylacetic acid. β-(3-methoxy-4-benzyloxy)-phenylethylamine (0.8 g), 0.84 g of the methyl ester of 4-benzoyloxyphenylacetic acid, and 0.5 ml of dry pyridine were heated for 5 hours at 185-190°. After two recrystallizations from alcohol the product melted at 131-132°. It gave no mixed melting point depression with the β-(3-methoxy-4-benzyloxy)-phenylethyl amide of benzoic acid.

Found %: N 4.06, 3.70. $C_{23}H_{23}O_3N$.

Calculated %: N 3.88.

β-(3-Methoxy-4-benzyloxy)-phenylethylamide of benzoic acid. A solution of 0.6 g of the hydrochloride of β-(3-methoxy-4-benzyloxy)-phenylethylamine was suspended in 10 ml of chloroform and treated, a little at a time, with shaking, with 0.24 ml of benzoyl chloride and a solution of 0.16 g of caustic soda in 5 ml of water, in such a way that the solution was alwaysweakly alkaline. The chloroform layer was separated, washed with dilute hydrochloric acid and with water, and dried over sodium sulfate. After evaporating off the chloroform there remained a colorless powder of mp 130-132°. Yield 0.7 g (98%). After recrystallization from ethyl alcohol or ethyl acetate the mp was 131-132°.

Found %: C 76.67; H 6.05; N 3.96. $C_{23}H_{23}O_3N$.

Calculated %: C 76.45; H 6.37; N 3.88.

β-(3-Methoxy-4-benzyloxy)-phenylethylamide of 4-benzoyloxy-phenylacetic acid (X). 4-Benzoyl-oxyphenylacetic acid (0.41 g) was mixed with 1.25 ml of thionyl chloride and heated to 50° in the course of 2 hours. Excess of thionyl chloride was distilled off in vacuo, and the residue was dissolved in 16 ml of chloroform. At the same time 0.41 g of β-(3-methoxy-4-benzyloxy)-phenylethylamine was mixed with 15 ml of chloroform, and the prepared solution of the chloroanhydride of 4-benzoyloxyphenylacetic acid, together with about 3 ml of a 5% solution of caustic soda, were added, a little at a time, with shaking, in such a way that the solution remained weakly alkaline. After shaking for 20 minutes the chloroform layer was separated and washed with dilue (1:1) hydrochloric acid and with water. After removal of the chloroform and extraction of the residue with ether, a colorless powder was obtained. Yield 0.58 g (73.4%). After recrystallization from ethyl alcohol the mp was 142-143°.

Found %: N 2.97, 2.96. $C_{31}H_{29}O_5N$.

Calculated %: N 2.83.

β-(3-Methoxy-4-benzyloxy)-phenylethylamide of 4-methoxymethoxyphenylacetic acid (XI). β-(3-Methoxy-4-benzyloxy)-phenylethylamine (1 g), 0.84 g of the methyl ester of 4-methoxymethoxy-phenylacetic acid and 0.8 ml of pyridine were heated together for 5 hours at 185-195°. The pyridine was evaporated off in vacuo, and the residue was dissolved in chloroform and washed with 5% hydrochloric acid and with water. After removal of the solvent the residue was ground with ether. Yield 0.41 g (23.6%) After recrystallization from 80% alcohol the mp was 96-97°.

Found %: C 71.79; H 6.78; N 3.44, 3.40. $C_{26}H_{29}O_5N$.

Calculated %: C 71.72; H 6.65; N 3.22.

β-(3-Methoxy-4-benzyloxy)-phenylethylamide of 4-carbomethoxyphenylacetic acid (XII). This was prepared from 0.72 g of 4-carbomethoxyphenylacetic acid and 0.87 g of β-(3-methoxy-4-benzyloxy)-phenylethylamine as described for substance (X). The yield was 0.63 g (41%) of mp 96-98°. After two recrystallizations from ethylacetate the mp was 102-104°.

Found %: C 69.15; H 6.08; N 3.28, 3.31. $C_{26}H_{27}O_6N$.

Calculated %: C 69.48; H 6.01; N 3.12.

β-(3-Methoxy-4-benzyloxy)-phenylethylamide of 4-chlorophenylacetic acid (XIII). This was obtained from 2.04 g of 4-chlorophenylacetic acid [6] and 3.08 g of β-(3-methoxy-4-benzyloxy)-phenyl-ethylamine. The yield was 3.54 g (72%) of the crude product of mp 117-118°. After two recrystallizations from methyl alcohol the product had a mp of 124-125°.

Found %: C 70.19; H 5.85; N 3.65, 3.65. $C_{24}H_{24}O_3N$.

Calculated %: C 70.33; H 5.86; N 3.42.

β-(3-Methoxy-4-benzyloxy)-phenylethylamide of 4-nitrophenylacetic acid* (XIV). This was prepared from 1 g of 4-nitrophenylacetic acid [7] and 1.12 g of β-(3-methoxy-4-benzyloxy)-phenylethyl-amine. Yield 1.05 g (51.7%). After two recrystallizations from alcohol the mp of the product was 132-133°.

Found %: N 6.48, 6.39. $C_{24}H_{24}O_5N_2$.

Calculated %: N 6.66.

β-(3-Methoxy-4-benzyloxy)-phenylethylamide of 3,4-dimethoxy-5-bromophenylacetic acid (XV). β-(3-Methoxy-4-benzyloxy)-phenylethylamine (2.1 g), 2.3 g of the methyl ester of 3,4-dimethoxy-5-bromo-phenylacetic acid [8], and 0.8 g of dry pyridine were heated together for 5 hours at 185-190°. The product was worked up as before. Yield 1.4 g (34.2%). After two recrystallizations from alcohol the product had a mp of 125-127°.

Found %: C 60.77; H 5.15; N 2.92, 2.91. $C_{26}H_{28}O_5N$.

Calculated %: C 60.70; H 5.44; N 2.73.

Experiment on the closure of the isoquinoline nucleus starting from the β-(3-methoxy-4-benzyloxy)-phenylethylamide of 4-benzoyloxy-phenylacetic acid. A mixture of 0.32 g of the amide with 0.35 ml of freshly distilled phosphorus oxychloride and 2 ml of toluene was heated to boiling for 1.5 hours. The toluene and excess of phosphorus oxychloride were distilled off in vacuo. The thick dark brown residue was dissolved by heating in 2 ml of ethyl alcohol. A crystalline precipitate separated. Yield 0.2 g. After recrystallization from ethyl alcohol the mp of the product was 212-213°. It gave no mixed melting point depression with the hydrochloride of 1-phenyl-6-methoxy-7-benzyloxy-3,4-dihydroisoquinoline.

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*The amide and the corresponding dihydroisoquinoline were prepared jointly by E. M. Merson and M. I. Lerner.

Found %: N 3.48, 3.41. $C_{23}H_{22}O_2N$.

Calculated %: N 3.69.

The hydrochloride of 1-(4'-methoxymethoxybenzyl)-6-methoxy-7-benzyloxy-3,4-dihydroisoquinoline (XVI). A solution of 0.3 g of phosphorus pentachloride in 4 ml of dry chloroform was added to a cold solution of 0.3 g of the β-(3-methoxy-4-benzyloxy)-phenylethylamide of 4-methoxymethoxyphenyl-acetic acid in 2 ml of dry chloroform. The reaction mixture was allowed to stand at room temperature for 3 days. The precipitate formed was filtered off, washed with dry chloroform, and dried in a desiccator. Yield 0.18 g (58%). Mp 205-207° (darkened at 190°).

Found %: C 62.88; H 6.93; N 2.92. $C_{26}H_{28}O_4NCl \cdot 5H_2O$.

Calculated %: C 62.59; H 6.62; N 2.81.

After drying in vacuo at 110°,

Found %: C 68.83; H 6.59, N 3.19. $C_{26}H_{28}O_4NCl$.

Calculated %: C 68.79; H 6.18; N 3.08.

The hydrochloride of 1-(4'-nitrobenzyl)-6-methoxy-7-benzyloxy-3,4-dihydroisoquinoline (XVII). This was prepared similarly to the previous one from 1.05 g of the β-(3-methoxy-4-benzyloxy)-phenyl-ethylamide of 4-nitrophenylacetic acid. After the mixture had stood for three days the chloroform was distilled off in vacuo (without heating) and the residue was dissolved by heating with absolute alcohol. Shining yellow crystals were produced on cooling, which were recrystallized from alcohol. Yield 0.93 g (85%). Mp 206-207°.

Found %: C 65.46, 65.31; H 5.09, 5.08; N 6.58, 6.62. $C_{24}H_{23}O_4N_2Cl$.

Calculated %: C 65.68; H 5.24; N 6.38.

Hydrochloride of 1-(4'-carbomethoxybenzyl)-6-methoxy-7-benzyloxy-3,4-dihydroisoquinoline (XVIII). The β-(3-methoxy-4-benzyloxy)-phenylethylamide of 4-carbomethoxyphenylacetic acid (1 g) was dissolved in 6 ml of dry toluene, treated with 0.9 ml of phosphorus oxychloride and heated to boiling for 1.5 hours. Excess of phosphorus oxychloride and the toluene were distilled off in vacuo, and the residue was dissolved by heating with alcohol. The precipitate formed was filtered off. Yield 0.9 g (86%). After recrystallization from alcohol the mp of the product was 146-147°.

Found %: C 66.86; H 5.26; N 3.12. $C_{26}H_{26}O_5NCl$.

Calculated %: C 66.74; H 5.56; N 2.99.

Hydrochloride of 1-(3'-bromo-4'-methoxybenzyl)-6-methoxy-7-benzyloxy-3,4-dihydroisoquinoline [9] (XIX). This was obtained under the same conditions as for the previous compound from 1 g of the β-(3-methoxy-4-benzyloxy)-phenylethylamide of 3-bromo-4-methoxyphenylacetic acid. Yield 0.7 g (68.3%). After recrystallization from absolute alcohol the mp of the product was 207-208° (decomp.).

Found %: C 59.89; H 5.21; N 2.70, 2.79. $C_{25}H_{25}O_3NClBr$.

Calculated %: C 59.71; H 4.97; N 2.78.

The picrate of the dihydroisoquinoline derivative (XIX) had a mp of 185-186° (decomp.).

Found %: N 8.07, 8.28. $C_{31}H_{27}O_{10}N_4Br$.

Calculated %: N 8.06.

Picrate of 1-(3',4'-dimethoxy-5'-bromobenzyl)-6-methoxy-7-benzyloxy-3,4-dihydroisoquinoline (XX). This was obtained similarly to the two previous compounds from the β-(3-methoxy-4-benzyloxy)-

-phenylethylamide of 3,4-dimethoxy-5-bromophenylacetic acid. After two recrystallizations from alcohol the picrate had a mp of 193-194°.

Found %: N 7.89, 7.95. $C_{32}H_{29}O_{11}N_4Br$.

Calculated %: N 7.72.

SUMMARY

1. There have been prepared and characterized a series of substituted 1-benzyl-3,4-dihydroisoquinolines which can be used as starting materials for the synthesis of bisbenzylisoquinoline alkaloids.

2. Some intermediate compounds for the synthesis of substituted 1-benzyl-3,4-dihydroisoquinolines have been prepared and characterized.

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* In Russian.

INVESTIGATION OF ISOCOUMARIN DERIVATIVES

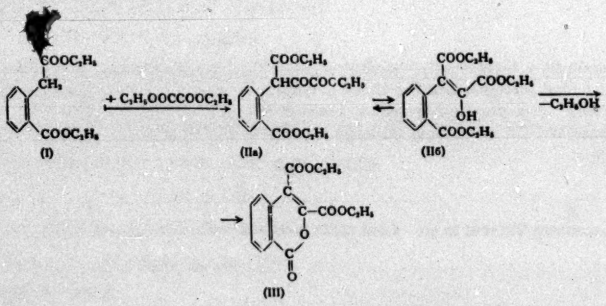
II. PREPARATION AND SOME REACTIONS OF DIETHYL ESTERS OF ISOCOUMARIN-3,4-DICARBOXYLIC ACIDS

N. N. Vorozhtsov and A. T. Petushkova*

By the condensation of the dimethyl ester of homophthalic acid with the dimethyl ester of oxalic acid under the influence of metallic sodium in ether solution, one of us, together with L. N. Bogusevich, obtained the dimethyl ester of isocoumarin-3,4-dicarboxylic acid [1]. Isocoumarin-3-carboxylic acid was obtained by heating the above substance to boiling with concentrated hydrochloric acid. Comparatively recently this method of synthesizing isocoumarin-3-carboxylic acid was used by Haworth and his coworkers [2] for the preparation of 5,6,7-trimethoxyisocoumarin-3-carboxylic acid, a product obtained by the degradation of methylated derivatives of bergenin [3] (contained in the roots of badan) and of chebulinic acid [4] (from myrobalans).

The English investigators were not familiar with our work and gave an inaccurate account of it [2]. In the paper they cited [1] we investigated not only the production of isocoumarin-3-carboxylic acid from the ester of the 3,4-dicarboxylic acid, but also the method of preparing the previously unknown ester used by the English investigators to make the ester of 5,6,7-trihydroxycoumarin-3,4-dicarboxylic acid (from the corresponding substituted homophthalic acid). They merely used potassium ethylate as a condensing agent instead of metallic sodium.

In an investigation of the condensation of the diethyl ester of oxalic acid with the ethyl ester of homophthalic acid (I) in the presence of metallic sodium, it was found that the highest yield of the diethyl ester of isocoumarin-3,4-dicarboxylic acid (III) (67% of pure product) was obtained in the absence of solvent (ether was only added at the end of the reaction). On condensation the primary product, which is unknown in the pure state, was the triethyl ester of o-carboxyphenyloxalolacetic acid (IIa) and (IIb), and this changes into III on heating.



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*From the thesis of A. T. Petushkova (1950).

On boiling with hydrochloric acid (III) is readily converted (84% yield) into isocoumarin-3-carboxylic acid (IV). The same product is also readily obtained by heating (III) with water to 180-190° in a sealed tube.

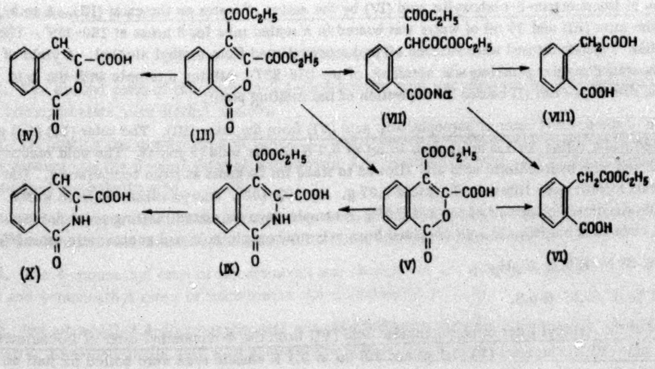
By acting on (III) with hydrochloric acid under milder conditions (3 hours at 68-72°), we obtained the monoethyl ester of isocoumarin-3,4-dicarboxylic acid (V). The formation of isocoumarin-3-carboxylic acid (IV) was also noted as the result of prolonged action of hydrochloric acid at 68-72°. The free isocoumarin-3,4-dicarboxylic acid was not obtained; evidently, with this compound, the carboxyl group in the 4 position splits off rapidly in an acid medium even at 70°.

With the acid ester of isocoumarin-3,4-dicarboxylic acid (V), the esterified carboxyl group is in position 4. This was shown by heating (V) with two equivalents of 0.2 N caustic soda when we obtained the β-ethyl ester of homophthalic acid (VI), identified by mixed melting point with an authentic specimen. The same ester of homophthalic acid was obtained by the action of 3 equivalents of 0.2 N caustic soda on (III). The action of four or more equivalents of alkali on (III) led to the formation of the free homophthalic acid (VII). Of particular interest in this case is the extraordinary ease of rupture of the carbon-carbon bond. The reaction evidently proceeds through the stage of the diethyl ester of o-carboxyphenyloxaloacetic acid (VII) formed by the rupture of the lactone ring in (III). The rupture of the carbon-carbon bond on heating with caustic soda solution takes place even with the preservation of a complex ester grouping in the degradation product (VI).

Haworth and his co-workers [2] observed the formation of the acid ester on treating their dimethyl ester of 5,6,7-trimethoxycoumarin-3,4-dicarboxylic acid with dilute sulfuric and acetic acids. In view of our results, their hypothesis that the acid ester was esterified in the 4 position is most probably correct.

On heating (III) in a sealed tube with 13% aqueous ammonia to 130-140°, we obtained (as the result of simultaneous replacement of oxygen by an imino group and hydrolysis of one ester group), the monoethyl ester of isocarbostyril-3,4-dicarboxylic acid (IX). The structure of this acid ester was established by its smooth and rapid formation at room temperature by the action of ammonia solution on the 4-ethyl ester of isocoumarin-3,4-dicarboxylic acid (V). It follows that in the acid ester of isocarbostyril-3,4-dicarboxylic acid the esterified carboxyl group is again in the 4 position.

On heating with hydrochloric acid to 170-180° the monoethyl ester of isocarbostyril-3,4-dicarboxylic acid (IX) gave isocarbostyril-3-carboxylic acid (X). This shows that also in isocarbostyril-3,4-dicarboxylic acid the carboxyl group in the 4 position splits off relatively easily (in contrast to the carboxyl group in position 3).



EXPERIMENTAL

The diethyl ester of homophthalic acid (I) was obtained by the action of excess of ethyl iodide on the silver salt of homophthalic acid at room temperature [5]; bp 292-293°.

Preparation of the diethyl ester of isocoumarin-3,4-dicarboxylic acid (III). Diethyl homophthalate (I) (10.2 g), 8 g of diethyl phthalate, and 1 g of thin slices of sodium metal were placed in a flask, closed by a calcium chloride tube, at room temperature. After 24 hours the reaction mixture was diluted with 10 ml of absolute alcohol and allowed to stand for a further 24 hours. The product was then treated carefully (a little of the sodium had not reacted) with 50-60 ml of water and shaken vigorously until the precipitate had all dissolved. The upper ether layer was separated and the water was extracted 2-3 times with ether. The yellow colored water layer was acidified with conc. H_2SO_4 until acid to congo red. The heavy oil formed was extracted with ether. The residue left after distilling off the ether gave a red-violet coloration (reaction for enols) with ferric chloride in alcohol solution. To close the isocoumarin ring the oil was heated for 2 hours at 100-105° until it no longer gave a reaction with ferric chloride. The crystals, which separated from the cold product in the course of 8-12 hours, were separated, washed with alcohol and recrystallized from anhydrous alcohol. The diethyl ester of isocoumarin-3,4-dicarboxylic acid (III) (8 g, 67%) was obtained in the form of granular chamfered platelets. Mp 65-66°. The product was insoluble in 0.1 N caustic soda or caustic potash, in the cold or on heating to 90°.

Found %: C 62.1; H 5.2; OC_2H_5 31.1. $C_{11}H_4O_4(OC_2H_5)_2$.

Calculated %: C 62.1; H 4.8; OC_2H_5 31.0.

Preparation of the 4-monoethyl ester of isocoumarin-3,4-dicarboxylic acid (V). A mixture of 0.2 g of (III) and 10 ml of 37% hydrochloric acid was heated under reflux on a water bath at 68-72° until the ester had completely dissolved (3 hours). The solution was poured into 5 ml of cold water. The colorless needles formed were filtered off and washed with water. Yield 0.14 g (83%). Mp 144.5-145°.

Found %: C 59.7; H 3.8. $C_{13}H_{10}O_6$.

Calculated %: C 59.5; H 3.8.

Preparation of isocoumarin-3-carboxylic acid (IV) by the action of hydrochloric acid on the ester (III). A mixture of 0.2 g of the ester (III) and 10 ml of 10% hydrochloric acid was boiled under reflux for 3 hours. The needlelike crystals formed on cooling were filtered off and recrystallized from methyl alcohol. A yield of 0.11 g (84%) of colorless shining platelets was obtained. Mp 236-237°. Mixing a sample with the acid obtained from the dimethyl ester (I) caused no depression of the melting point. Isocoumarin-3-carboxylic acid was also formed by prolonged (28 hours) heating of the ester (III) with hydrochloric acid at 68-72°.

Preparation of isocoumarin-3-carboxylic acid (IV) by the action of water on the ester (III). A mixture of 0.1 g of the ester (III) and 10 ml of water was heated in a sealed tube for 3 hours at 180-190°. The colorless needlelike crystals formed were filtered off and recrystallized from methyl alcohol. A yield of 0.05 g (77%) of beautiful regular platelets was obtained, of mp 236-237°. Mixing a sample with the acid obtained from the dimethyl ester (I) caused no depression of the melting point.

Preparation of the β-ethyl ester of homophthalic acid (VI) from the ester (III). The ester (III) (0.2 g, 1 mole) was boiled under reflux for 1.5 hours with 10 ml of 0.2 N caustic soda (3 mole). The cold reaction mixture was acidified with hydrochloric acid and allowed to stand for 24 hours at room temperature. The needlelike crystals formed were filtered off. Yield 0.07 g. Mp 102-103°. Recrystallization from water gave 0.03 g of thin needle-like crystals of mp 105-106°. A sample gave no mixed melting point depression with the β-ethyl ester of homophthalic acid obtained from o-bromobenzoic acid and acetoacetic ester [6].

Found %: C 63.5; H 5.7. $C_{11}H_{12}O_4$.

Calculated %: C 63.5; H 5.8.

Preparation of the β-ethyl ester of homophthalic acid (VI) from the 4-monoethyl ester of isocoumarin-3,4-dicarboxylic acid (V). The ester (V) (0.1 g) and 8.0 ml of 0.1 N caustic soda were boiled for half an hour on an oil bath. The cold solution was treated with hydrochloric acid until acid to congo red. Colorless crystals deposited on standing. Mp 105-106°. The product gave no mixed melting point depression with an authentic sample of the β-ethyl ester of homophthalic acid.

Preparation of homophthalic acid (VIII). A mixture of 0.1 g (1 mole) of the ester (III) with 7 ml of 0.2 N caustic soda (5 mole) was boiled under reflux for 3 hours. The solution was cooled and acidified with hydrochloric acid. A crystalline deposit of homophthalic acid formed in 24 hours. The deposit was filtered off, washed with water and recrystallized from glacial acetic acid and water. A yield of 0.028 g (45.1%) of homophthalic acid was obtained. Mp 180-181°. The product gave no mixed melting point depression with an authentic sample of homophthalic acid.

Reaction of the ester (III) with an aqueous solution of ammonia. The ester (III) (1 g) and 25 ml of 13% ammonia solution were heated in a sealed tube for 3 hours at 130-140°. The reaction mixture was made acid to congo red with hydrochloric acid. The colorless amorphous precipitate formed was filtered off, washed with water, and recrystallized from 95% alcohol. The yield was 0.48 g (53%) of colorless platelets of the 4-monoethyl ester of isocarbostyril-3,4-dicarboxylic acid (IX). Mp 297-298°.

Found %: C 59.4; H 4.4; N 5.9; OC_2H_5 (Fibek's method [7]) 16.9. $C_{11}H_6O_4N(OC_2H_5)$.

Calculated %: C 59.8; H 4.2; N 5.4; OC_2H_5 17.2.

Preparation of the ester of the 4-monoethyl ester of isocarbostyril-3,4-dicarboxylic acid (IX) from the ester (V). The ester (V) (0.2 g) was dissolved in 5 ml of 13% ammonia. The solution was shaken frequently for 20 minutes at room temperature and then acidified with 20% hydrochloric acid. The amorphous colorless precipitate formed was filtered off, washed with water, and recrystallized from 95% alcohol. The yield was 0.19 g (95%) of colorless platelets. Mp 297-298°. The product gave no mixed melting point depression with the ester (IX), obtained from (III).

Preparation of isocarbostyril-3-carboxylic acid (X). A mixture of 0.1 g of the 4-monoethyl ester of isocarbostyril-3,4-dicarboxylic acid (IX) and 10 ml of 37% hydrochloric acid was heated for 3 hours in a sealed tube at 170-180°. The reaction mixture was poured into water. The resulting white flocculent precipitate was filtered off and washed with water. After recrystallization from glacial acetic acid and then from water, the product was in the form of long needle-shaped crystals (resembling asbestos) of mp 320.5-321.5°. The mp given in the literature [8] is 320°. The product gave no mixed melting point depression with isocarbostyril-3-carboxylic acid obtained from isocoumarin-3-carboxylic acid.

The methyl ester of isocarbostyril-3-carboxylic acid was obtained by the action of diazomethane on the acid in ether solution. It crystallized from methyl alcohol in the form of thin long needles of mp 159-160°.

Found %: N 6.9. $C_{11}H_9O_3N$.

Calculated %: N 6.9.

SUMMARY

1. The diethyl ester of isocoumarin-3,4-dicarboxylic acid was obtained by the condensation of diethyl homophthalate with diethyl oxalate.

2. On heating the diethyl ester of isocoumarin-3,4-dicarboxylic acid with hydrochloric acid the primary product was the 4-ethyl ester of isocoumarin-3,4-dicarboxylic acid, and the final product was isocoumarin-3-carboxylic acid.

3. Homophthalic acid and its β-ethyl ester were obtained by heating the diethyl and 4-monoethyl esters of isocoumarin-3,4-dicarboxylic acid with a 0.2 N solution of caustic soda.

4. The 4-monoethyl ester of isocarbostyril was obtained by the action of aqueous ammonia on the diethyl and 4-monoethyl esters of isocoumarin-3,4-dicarboxylic acid.

5. Isocarbostyril-3,4-dicarboxylic acid was obtained by heating the 4-monoethyl ester of isocarbostyril-3,4-dicarboxylic acid with hydrochloric acid to 170-180°.

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SYNTHESIS OF SOME DERIVATIVES OF β-PHENYLCYSTEINE

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In view of the recent appearance in the literature of a report [1] on the marked antitubercular activity of some S-alkyl substituted mercaptoamino acids, particularly of S-ethylcysteine, it was of interest to investigate the action on the tubercle bacillus of other mercaptoamino acids and their derivatives.

The subject of this paper is the synthesis of β-phenylcysteine and of its S-alkyl substituted and some other derivatives.

The synthesis of phenylcysteine from 2-thiothiazolones was investigated by Cook and his co-workers [2,3] in 1948. But their method of preparing the 2-thiothiazolones gave a poor yield and was somewhat cumbersome; so that it seemed worth investigating the synthesis of β-phenylcysteine by other means. Another method of synthesis would also be useful for preparing phenylcysteines with substituents in the benzene ring, since these could only be obtained with great difficulty by Cook's method.

In 1951 a method was published for the synthesis of cysteine [4] based on the addition of thiourea, or its hydrochloride, to α-chloroacrylic acid, with the formation of an intermediate salt of isothiourea, and subsequent ring closure to give a thiazole derivative. On reduction with sodium amalgam the latter was converted to cysteine.

It was expected that interaction of α-chlorocinnamic acid with thiourea hydrochloride in the same way might provide a practicable synthesis of β-phenylcysteine. But our experiments on the condensation of α-chlorocinnamic acid either with free thiourea, or with its mineral acid salts, did not lead to the formation of the corresponding isothiourea compound. Only the starting materials and an insignificant quantity of a substance containing sulfur, nitrogen, halogen, and a carboxyl group could be recovered from the reaction products; the structure of this substance was not determined.

Another method considered for the production of phenylcysteine was synthesis from serine derivatives, analogous to the production of cysteine and cystine from serine [6-8]. The possibility was investigated of replacing the hydroxy group in phenylserine by chlorine with the object of subsequently replacing the halogen by a mercapto group. Both acetyl chloride [7] and chloroform [8] were tried as media for the condensation of the methyl ester of phenylserine hydrochloride with phosphorus pentachloride. But the replacement of the hydroxyl group in phenylserine by chlorine took place with a very poor yield, particularly when the reaction was carried out in chloroform. When substituents were introduced into the benzene ring, particularly a nitro group in the para-position, no reaction generally occurred. So that this method could not be used for the synthesis of phenylcysteine.

The attempted direct replacement of the hydroxyl group in phenylserine by a mercapto group also gave an unsatisfactory result. When the ethyl ester of N-benzoylphenylserine reacted with phosphorus pentasulfide the main product was not phenylcysteine but 2,5-diphenyl-4-thiazolinecarboxylic acid. An attempt to carry out this reaction with the ethyl ester of N-benzoyl-p-nitrophenylserine resulted in considerable tar production because of the high melting point of the ester, and no sulfur containing product was obtained.

The reaction of phosphorus pentasulfide with the ethyl ester of N-tritylphenylserine was also investigated; in this case there was considerable tar formation and triphenylmethane was liberated.

Thus all the methods selected for the synthesis of phenylcysteine were unsatisfactory. It is evident that the phenyl radical has a powerful influence in greatly reducing the mobility of reactive groups in the molecule.

We obtained phenylcysteine from the amide of glycocoll and 2-thiothiazolone by the method referred to above [3]; and the yields agreed with those quoted in the literature.

An attempt to obtain p-nitrophenylcysteine by this method did not succeed, as the stage of the conversion of 4-(p-nitrobenzylidene)-thiothiazolone into the corresponding phenylthiothiazolidonecarboxylic acid did not take place: probably the presence of the nitro group prevented this rearrangement.

The disulfide of phenylcysteine (diphenylcystine) was prepared and also the ethyl ester of phenylcysteine hydrochloride and its disulfide. Besides these we synthesized some N-substituted phenylcysteines and their disulfides.

Three possible methods were tried for preparing S-alkyl substituted phenylcysteines — condensation of a mercaptoamino acid hydrochloride with an alkyl halide in aqueous alkali [9], or in alcohol in the presence of alkali [10], and reduction of the disulfide of phenylcysteine with metallic sodium in liquid ammonia in the presence of an alkyl halide.

The first two methods did not give S-alkyl substituted derivatives; the products were only disulfides in all cases. But the S-methyl-, S-ethyl- and S-butyl-phenylcysteines were obtained by the reaction with sodium in liquid ammonia and the corresponding alkyl halides. In some of the experiments a mixture of disulfide, its hydrochloride and mercapto compound was used.

Both the S-alkylphenylcysteines and their hydrochlorides were very difficult to purify, and the low carbon content found clearly indicated the presence of water of crystallization, which was not evolved at normal temperature. Attempts to dry these compounds in vacuo at higher temperature (about 50°) led to gradual decomposition.

All the substances prepared, including phenylcysteine and its intermediates, were investigated in the chemotherapy department of the All Union Chemico-Pharamaceutical Scientific Research Institute (Director Prof. G. H. Pershin)*. It was found that only the hydrochlorides of the esters of phenylcysteine and diphenylcystine showed a fairly marked tuberculostatic activity in vitro (inhibition of the growth of Mycrobacterium tuberculosis strain $H_{37}Rv$ cultured without serum at 1:1,000,000),but in the presence of serum the activity was sharply reduced (1:16,000). The other substances showed negligible or no activity. 2-Thiothiazolone showed some activity towards the influenza virus.

EXPERIMENTAL

Ethyl ester of phenylcysteine hydrochloride. A vigorous stream of dry hydrogen chloride was passed through 6.2 g of recrystallized phenylcysteine hydrochloride [3] (mp 199-200°) in 150 ml of anhydrous alcohol, for half an hour while cooling in iced water and then while heating to boiling; after the precipitate had dissolved the solution was heated for another 30 minutes and allowed to stand overnight. The alcohol was evaporated in vacuo and the residue was treated with sodium bicarbonate. The resulting oil was taken up in ether and, after drying,the ether solution was saturated with dry hydrogen chloride. The white crystals which formed in 24 hours were filtered off, dissolved in a small quantity of alcohol, and again precipitated with ether. Yield 2.2 g; mp 149-150°. The colorless crystals were readily soluble in water and in alcohol but were insoluble in ether; the material gave a positive reaction for the mercapto group.

Found %: C 50.76; H 6.28. $C_{11}H_{15}O_2NS \cdot HCl$.

Calculated %: C 50.47; H 6.11.

From the mother liquor, after dilution with ether, an additional quantity of a mixture of the esters of phenylcysteine and the disulfide was obtained.

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*The investigation was made by S. N. Milobanova and T.N. Zikova.

Ethyl ester of N-tritylphenylcysteine. A mixture of 1.3 g of the ethyl ester of phenylcysteine hydrochloride with 15 ml of dry chloroform was cooled to 0° and treated, with stirring, with 1.5 ml of triethylamine and then with 1.4 g of triphenylchloromethane (mp 110-112°) added in portions at 0°. After standing for a few hours at room temperature the solution was washed with water, then with dilute hydrochloric acid, and again with water, and dried over calcined magnesium sulfate. The solvent was evaporated off, and the remaining caramel-like syrup was warmed with a small quantity of anhydrous alcohol; after treatment with charcoal and cooling there was 0.6 g of an oily material which slowly crystallized. After two recrystallizations from alcohol the mp was 154-156°. The colorless crystals were readily soluble in alcohol but insoluble in water or hydrochloric acid.

Found %: C 76.71; H 6.22. $C_{30}H_{29}O_2NS$.

Calculated %: C 77.00; H 6.22.

The disulfide of phenylcysteine (diphenylcystine). Aqueous caustic soda (18%) was added drop by drop to a solution of 0.74 g of phenylcysteine hydrochloride (mp 199-200°) in 20 ml of water until the liquid was neutral to litmus. A stream of air was then blown through the liquid for 1 hour. A white precipitate formed gradually over a period of 2 hours. The mixture was allowed to stand overnight, and the precipitate was filtered off and washed with alcohol and with ether. The colorless crystals, of mp 205-206°, were insoluble in water and in alcohol. The reaction for the mercapto group was negative.

Found %: C 54.74; H 5.20; N 7.24; S 16.20. $C_{18}H_{20}O_4N_2S_2$.

Calculated %: C 55.10; H 5.10; N 7.15; S 16.30.

The disulfide was obtained from technical unrecrystallized phenylcysteine (mp 187-188°) without the need for additional oxidation by atmospheric oxygen.

Ethyl ester of diphenylcystine hydrochloride. A mixture of 6.7 g of phenylcysteine hydrochloride with 160 ml of anhydrous ethyl alcohol was cooled and stirred while it was saturated with hydrogen chloride; the stream of hydrogen chloride was then continued while the liquid was heated on a water bath until all the solid had dissolved. A stream of air was blown through the alcoholic solution for a few hours, after which the alcohol and hydrogen chloride were removed in vacuo. The residue was treated with sodium bicarbonate, and the oil formed was extracted with ether. The ether solution was dried, saturated with dry hydrogen chloride, and allowed to stand at room temperature. Over several days a white precipitate formed which did not give a qualitative reaction for the mercapto group. Yield 6.55 g. The material was purified by reprecipitation from alcohol with dry ether. The colorless crystals were readily soluble in water, alcohol, and acetic acid, but insoluble in ether. Mp 191°.

Found %: C 50.27; H 5.86; S 12.40; Cl 13.61. $C_{22}H_{28}O_4N_2S_2 \cdot 2HCl$.

Calculated %: C 50.67; H 5.75; S 12.28; Cl 13.63.

Ethyl ester of N,N'-dibenzoyldiphenylcystine. A mixture of 0.7 g of the ethyl ester of diphenylcystine hydrochloride with 20 ml of 10% soda and 50 ml of ether was carefully shaken, and then 0.38 g of benzoyl chloride was added slowly with shaking at intervals. A precipitate separated from the ether layer over a period of two days, which was filtered off, washed with sodium bicarbonate and with ether, and twice recrystallized from aqueous acetic acid and then from a small quantity of alcohol. Yield 0.5 g; mp 147-149°. The colorless crystals were insoluble in water, hydrochloric acid or sodium bicarbonate solution, but dissolved readily in hot alcohol or acetic acid.

Found %: C 65.80; H 5.52. $C_{36}H_{36}O_6N_2S_2$.

Calculated %: C 65.90; H 5.42.

Methyl ester of β-chlorophenylalanine hydrochloride. Phosphorus pentachloride (4.5 g) was added in three portions, with shaking and continuous cooling, to a cold suspension of 3 g of the methyl ester of phenylserine hydrochloride in 30 ml of redistilled acetyl chloride. The shaking was continued for about an hour, and then the yellow solution was allowed to stand overnight in a refrigerator. The white precipitate formed (0.6 g) was reprecipitated with ether from alcohol solution. Mp 177° (decomp.). The colorless crystals were readily soluble in water and in alcohol but insoluble in ether.

Found %: Cl (total) 28.05; Cl' 14.04. $C_{10}H_{12}O_2NCl \cdot HCl$.

Calculated %: Cl (total) 28.40; Cl' 14.20.

Ethyl ester of N-benzoyl-p-nitrophenylserine. A mixture of 2.9 g of the ethyl ester of p-nitrophenylserine hydrochloride with 57 ml of 10% soda and 150 ml of ether was carefully shaken, and a solution of 1.41 g of benzoyl chloride in a small quantity of ether was added slowly with periodic shaking. In time a precipitate formed in the ether layer which was filtered off, and washed with soda, water, dilute hydrochloric acid and again with water. Yield 2.15 g; mp 158-159°.

Found %: C 60.31; H 5.10. $C_{18}H_{18}O_6N_2$.

Calculated %: C 60.40; H 5.06.

Reaction of the ethyl ester of N-benzoylphenylserine with phosphorus pentasulfide. A mixture of 5 g of the ethyl ester of N-benzoylphenylserine (mp 100-103°) and 1.4 g of phosphorus pentasulfide (100% excess) was carefully ground in a mortar and heated in an open tube in an oil bath. At a bath temperature of 105-110° the mixture liquefied and began to give off gas. Heating at this temperature was continued until gas was no longer evolved (1-1.5 hours) and then for 8 hours at 130° with periodic stirring by a rod. The reaction product, while still hot, was added to 70 ml of ethyl alcohol, and the alcohol solution was treated with charcoal and poured into 600 ml of water. The oil formed was extracted with ether, the ether solution was washed with water and dried, and the ether was evaporated in vacuo. The yellow oily substance remaining (it was insoluble in a solution of sodium bicarbonate or acid, soluble in carbon disulfide), was boiled for 7 hours with 70 ml of hydrochloric acid, and the mixture was then extracted with ether. The water layer was treated with charcoal by heating and evaporated a little in vacuo. Yellow crystals were formed on cooling; these were filtered off, washed with water and recrystallized twice from hot hydrochloric acid. Yield 1.65 g, mp 165-166°. The product was soluble in sodium bicarbonate solution and in alcohol, insoluble in ether. The reaction for the mercapto group was negative; a sample mixed with phenylcysteine hydrochloride showed a depression of the melting point.

Found %: C 59.60; H 4.24; S 10.11; N 4.67; Cl 11.34. $C_{16}H_{13}O_2NS \cdot HCl$.

Calculated %: C 60.00; H 4.38; S 10.01; N 4.38; Cl 11.11.

The recrystallized material (0.2 g) was mixed with 2 ml of N NaOH, and the solution was filtered rapidly into 2 ml of glacial acetic acid. The precipitate formed was filtered off, washed with water and dried. After two recrystallizations from aqueous alcohol the mp was 139-140°. (The mp given in the literature for 2,5-diphenyl-4-thiazolinecarboxylic acid is 141° [12]).

Found %: C 67.77; H 4.76; S 11.44; COOH 15.94. $C_{16}H_{13}O_2NS$.

Calculated %: C 67.90; H 4.60; S 11.31; COOH 15.90.

Methyl ester of N-tritylphenylserine. A mixture of 2.31 g of the methyl ester of phenylserine hydrochloride with 20 ml of dry chloroform was cooled to 0°, and 3 ml of triethylamine was added with stirring. Freshly distilled triphenylchloromethane (2.8 g) was added to this solution at 0° with continuous stirring. After standing for a day and a half at room temperature the yellow solution was washed with water, with 2 N hydrochloric acid, and again with water, and dried over magnesium sulfate. After evaporating off the solvent the resulting caramel-like material was heated with 20 ml of ethyl alcohol. The hot alcoholic solution was decolorized with charcoal; crystals in the form of six edged prisms appeared on cooling. Recrystallization from alcohol gave a yield of 2.2 g, mp 136-138°.

Found %: C 79.38; H 6.33. $C_{29}H_{27}O_3N$.

Calculated %: C 79.63; H 6.17.

S-Methylphenylcysteine. A mixture of 30 ml of liquid ammonia, 2.56 g of phenylcysteine hydrochloride, and 1.23 g of diphenylcystine was cooled to −40°, and 0.9 g of metallic sodium was added gradually with stirring (until a blue color persisted for a few minutes). The reaction mixture was held at the same temperature, 1.5 ml of methyl iodide was added, and the solution was stirred continuously for 2 hours. After evaporating off the ether the residue was dissolved in 25 ml of water, and the aqueous layer was extracted with ether and made weakly acid to litmus with hydrochloric acid. The precipitate of small white crystals (2.5 g) was recrystallized several times from alcohol. Mp 158-159°.

Found %: S 15.04; N 6.67. $C_{10}H_{13}O_2NS$.

Calculated %: S 15.15; N 6.64.

S-Methylphenylcysteine hydrochloride was obtained in the form of colorless needles; after several recrystallizations from concentrated hydrochloric acid the mp was 165-166°.

Found %: C 47.87; H 6.25. $C_{10}H_{13}O_2NS \cdot HCl$.

Calculated %: C 48.48; H 5.66.

S-Ethylphenylcysteine. To 25 ml of liquid ammonia at −35 to −45° were added 1 g of diphenylcystine and then (in portions with vigorous stirring) 0.25 g of sodium. When the sodium had dissolved, 0.4 ml of ethyl bromide was added, and stirring was continued for another two hours at the same temperature. After evaporating off the ammonia the residue was dissolved in 20 ml of water, and the aqueous solution was extracted with ether and made weakly acid to litmus with concentrated hydrochloric acid. A white crystalline precipitate of S-ethylphenylcysteine (0.76 g) deposited over a period of several hours. After several recrystallization from concentrated hydrochloric acid the mp was 168-170°.

Found %: S 11.85; N 5.00; Cl 13.17. $C_{11}H_{15}O_2NS \cdot HCl$.

Calculated %: S 12.25; N 5.34; Cl 13.55.

S-Ethylphenylcysteine was obtained in the form of long colorless threads; after several recrystallizations from alcohol the mp was 153-154°.

Found %: N 5.98; S 14.51. $C_{11}H_{15}O_2NS$.

Calculated %: N 6.22; S 14.20.

S-Butylphenylcysteine. Phenylcysteine hydrochloride (2.18 g) and 1.37 g of diphenylcystine were added to 25 ml of liquid ammonia, and 0.755 g of sodium was added in portions with stirring to the mixture (at a temperature of −35 to −45°). After the sodium had dissolved, 2 ml of butyl iodide was added, and stirring was continued at the same temperature for 2 hours. The ammonia was evaporated off, the residue was dissolved in 25 ml of water, and the aqueous solution was extracted with ether and made weakly acid to litmus. The white precipitate formed was filtered off and washed with water. Yield 3.52 g. After several recrystallizations from alcohol the melting point was 157-159 .

Found %: C 61.03; H 7.78; N 5.39. $C_{13}H_{19}O_2NS$.

Calculated %: C 61.66; H 7.52; N 5.54.

S-Butylphenylcysteine hydrochloride was obtained in the form of colorless long prisms; after several recrystallizations from concentrated hydrochloric acid the mp was 155-157°.

Found %: C 53.80; H 7.18; N 5.05; Cl 12.30. $C_{13}H_{19}O_2NS \cdot HCl$.

Calculated %: C 54.00; H 6.93; N 4.84; Cl 12.29.

SUMMARY

1. Some derivatives of phenylcysteine have been prepared — the hydrochloride of its ethyl ester, N-tritylphenylcysteine, S-methyl-, S-ethyl- and S-butyl-phenylcysteine.

2. Diphenylcystine and its ester and di-N-benzoyl derivative have been prepared.

3. Attempts to prepare phenylcysteine by the reaction of α-chlorocinnamic acid with thiourea or from phenylserine derivatives were unsuccessful. In the course of this work some new derivatives of phenylserine were obtained.

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OIL OF CATALPA BIGNONIOIDES

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The oil of Catalpa bignoniodes is interesting because of its exceptional properties as a drier.

The genus Catalpa includes eight species, growing principally in China, Japan, India, and other countries in southern Asia and in Central America. It was found in Europe in 1726 [1]. In the Soviet Union it grows principally in the southern regions; it extends as far north as Moscow and Leningrad. It is found mainly in towns and suburban districts, being used as a decorative tree planted along roads and irrigation channels, in parks and gardens, and occasionally in separate groves. It is sometimes called "Adam's tree," which is incorrect since this name belongs to another tree, Paulonia imperialis, similar to Catalpa.

Catalpa bignonioides is the most widely distributed species of Catalpa in the towns and villages of Central Asia. It is a tree, reaching a height of 15 m and with a trunk 70 cm in diameter. The fruit is a long round pod containing 180-250 greenish-gray seeds. 1000 seeds weigh about 25 g.

Until now catalpa oil has been very little mentioned in literature; we found no mention of it in foreign literature; as regards Soviet sources, there was only a brief note in a newspaper [2] and an article [3] by I. K. Trosko in which the author mentioned the valuable properties of this oil as a drier, and an article by G. V. Lazuryevsky [4] which briefly mentioned the characteristics of the oil, pointed out its similarity to tung oil, and assumed that it contained eleostearic acid.

The catalpa oil we obtained[*] had a light-yellow color and had the following physical and chemical characteristics:

S. g. 0.942-0.944; refractive index 1.5001-1.5021; viscosity by Engler's method 21.9 (at 20°), 7.04 (at 50°); acid number 1.24; saponification number 191.5; ester value 190.26; Gener.number 96.4; Reichert-Meissel number 1.39; Polenske number 0.4; acetyl number 33.2; iodine number by Huble's method 171.0; thiocyanate number 96.7; diene number 27.0; mean molecular weight of the fatty acids 281.6; content of high-molecular saturated acids by Bertram's method 4.2%; content of unsaponifiable material by Spitz and Honig's method, 0.52%.

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[*] To obtain catalpa oil we dried the seeds at 60-65° for 3-5 days, turning them frequently with a shovel. The seeds were then divided into 3-5 segments each, and extracted by the method of successive infusion in three extractors (each with a capacity of 20 liters) which were all charged with 3.5-3.9 kg of material. 5-6 liters of extractive gasoline was added to each extractor. The extraction was carried out at 50-55° with periodical stirring. The solution of oil in benzine (micelle) was filtered through three layers of gauze after which the benzine was steam distilled at 65-70°. The fact that all the gasoline had been distilled off was checked by determining the flash point of the oil; when this was carried out in an open porcelain crucible by Brenken's method, it was found to be over 300°. The yield of oil was about 22%.

From a number of the characteristics sp. gr., refractive index, viscosity) catalpa oil most closely resembles tung oil. From its high iodine and thiocyanogen numbers it must be included among the good driers. Although its iodine number is almost the same as that for linseed oil, it has a much smaller thiocyanogen number. This suggests that catalpa oil contains highly-unsaturated fatty acids with conjugated double bonds. This is confirmed by the high value of the diene number which, although less than the value for tung oil, is far higher than for linseed, sunflower and cottonseed oils. This strongly favors the assumption that catalpa oil contains eleostearic acid which is a characteristic component of tung oil, distinguishing it from the majority of other vegetable oils and giving it its unique properties in processes of film formation.

For a qualitative determination of the acids with conjugated double bonds, particularly eleostearic acid, we obtained the spectral characteristics of tung and catalpa oil is isooctane solution by means of an ISP-22 quartz spectrograph. (Absorption bands in the 230-400 mμ region are absent in the spectrum of isooctane and we were therefore able to use it as a solvent in the spectrophotometric analyses of the oils.) Comparison of the spectral characteristics of tung and catalpa oils showed their considerable similarity. In particular, the presence of an absorption band at 258-280 mμ, which is characteristic for eleostearic acid definitely suggests that this acid is present in catalpa oil.

To determine quantitatively the composition of the mixture of fatty acids in catalpa oil, we made use of the above-mentioned chemical characteristics.

With 4.2% of unsaturated acids, the glyceride content was $4.2 \cdot 1.045 = 4.39\%$.

The theoretical diene number of eleostearic acid was 91.16, that of its triglyceride 87.23. The glyceride content of eleostearic acid in the investigated oil was, therefore, $\frac{27.100}{91.16} = 29.61\%$.

For 27 units of the diene number there were 27 units of the thiocyanogen and 54 units of the iodine number. For the glycerides of oleic, linoleic and linolenic acids there were, therefore, 117 units of the iodine and 69.7 units of the thiocyanogen number. Let us modify for this instance the equations for calculating the glyceridic composition of fats [5]*:

$$\begin{aligned} \mathrm{Ol} &= [100 - (N + E)] - 1.154\,(\mathrm{I.\ No.} - \mathrm{Th.\ No.}) \\ \mathrm{L} &= [100 - (N + E)] - 1.154\,(2\ \mathrm{Th.\ No.} - \mathrm{I.\ No.}) \\ \mathrm{Le} &= [100 - (N + E)] + 1.154\ \mathrm{Th.\ No.} \end{aligned}$$

Substituting the above values of the iodine and thiocyanogen numbers and the figures for the content of glycerides of saturated and unsaturated acids we obtain contents of 10.08%, 38.81%, and 15.77% for the glycerides of oleic, linoleic, and linolenic acids, respectively.

The above-described method for determining the fatty-acid composition of the oil cannot be considered as perfect since the method for determining the diene number is, itself, not free from errors. Spectrophotometric analysis makes it possible to carry out this determination with greater accuracy since fatty acids with two or more conjugated double bonds give characteristic, clearly defined absorption bands in the ultraviolet region of the spectrum.

There are references in papers [6-8] to the presence of two forms of eleostearic acid in tung oil, the qualitative ratio of the α- and β-isomers depending on a number of factors, in particular, the degree of ripeness of the tung nuts, the conditions and duration of storage of the nuts, the method of processing, etc. The β-isomer of eleostearic acid is of higher value for the production of materials for films and it, therefore, became necessary to determine the α- and β-forms of eleostearic acid separately as well as the total content of the acid. This may be carried out by O'Connor's method which is based on a certain difference in their absorption spectra: the maximum of the absorption spectrum of the α-isomer is 271.5 mμ, that of the β-isomer 269.0 mμ; the absorption curves of both isomers intersect at a point corresponding to 276.5 mμ, making it possible to determine their total content.

We determined the fatty-acid composition quantitatively by means of an SF-4 spectrophotometer.

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*Ol, L, Le, N and E are the content of the glycerides of oleic, linoleic, linolenic, saturated and eleostearic acids, respectively; I. No. is the iodine number; Th. No. is the thiocyanogen number.

All the determinations were carried out with solutions of the oils in isooctane in the 220-300 mμ region at a concentration of 0.05-0.08 g/liter and a thickness of 2 mm for the layer through which the rays passed. The absorption curve was drawn on the basis of measurements carried out on three samples of catalpa oil. The curve is shown in Fig. 1 (curve 1), which also gives the curve we obtained for tung oil (curve 2). When the curves are compared, the almost complete coincidence of the maxima, particularly evident at 269 mμ (this maximum is characteristic for the β-isomer of eleostearic acid) is very striking.

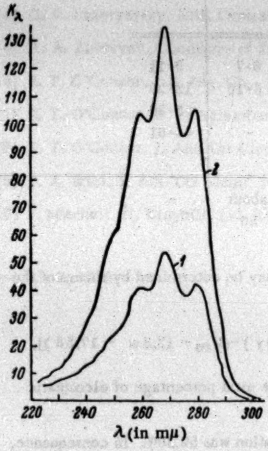

Fig. 1. Absorption curves of catalpa and tung oils. 1) Catalpa oil. 2) Tung oil.

To determine the total content of eleostearic acid and the separate contents of the α- and β-isomers we used O'Connor's equation [7]:

Total % of eleostearic acid = $0.8163\ K_{276.5}$

% of α-isomer = $2.375\ K_{269} - 2.7\ K_{271.5}$

% of β-isomer = $2.248\ K_{269} - 1.994\ K_{271.5}$

where K_λ is the absorption coefficient at a wavelength λ.

For the three investigated samples of catalpa oil we found values of between 38.33 and 41.45 for $K_{276.5}$, between 46.20 and 49.65 for $K_{271.5}$ and from 53.50 to 58.00 for K_{269}. From O'Connor's equation we, therefore, find a mean content of eleostearic acid of 32.60%, including 2.31% of the α-isomer and 29.22% of the β-isomer. For purposes of comparison we may mention that the sample of tung oil we investigated contained 5.06% of the α-isomer, 70.34% of the β-isomer, and a total eleostearic content of 75.40%.

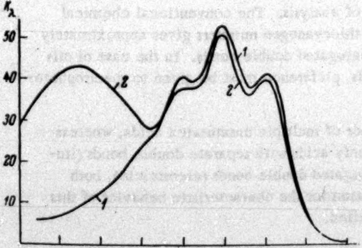

Fig. 2. The influence of alkaline isomerization on the absorption spectrum of catalpa oil. 1) Oil before isomerization. 2) Oil after isomerization.

Together with the eleostearic acid the content of diene compounds with conjugated double bonds in the oil may be determined from the formula:

% of dienes = $0.84\ [K_{233} - 0.138$ (% of α-acid) $-$
$-\ 0.175$ (% of β-acid) $- 0.07]$.

For the three samples of catalpa oil we obtained values of 8.3 to 13.25 for K_{233}, an average of 10.32. The corresponding mean content of diene acids was 4.05%.

We then subjected catalpa oil to alkaline isomerization, as described for other oils in literature [9,10]. We carried out a spectrophotometric investigation of the isomerized product at a solution concentration of 0.068 g/liter. The results are given in Fig. 2, where curves 1 and 2 refer to the oil prior to and after isomerization, respectively. From a comparison of the absorption curves it is evident that the absorption coefficient of the investigated sample after isomerization in the 250-280 mμ region is somewhat less in comparison with the initial oil, although the position of the maximum is retained; this indicates the absence of linolenic acid in the oil. The considerable increase in absorption at 230-240 mμ indicates the presence of linoleic acid in catalpa oil.

Fatty-Acid Composition of the Oils (as percentages)

Fatty Acids	Catalpa Oil		Tung oil	Linseed oil
	Data from chemical analysis	Data from spectrophotometric analysis		
Saturated	4.39	4.39	6-7	9-11
Oleic	10.08	10.13	8-10	13-29
Linoleic	38.81	48.83	-	15-30
Linolenic	15.77	-	-	44-61
Diene acids with conjugated double bonds	-	4.05	-	-
Eleostearic acids	30.95	32.60	about 80	-

The content of diene acids in the presence of eleostearic acid may be determined by means of the following equation:

$$\%\text{ of diene acids} = 1.086\,[(K'_{233} - 15.8'\alpha - 26.1'\beta - 19.38\gamma) - (K_{233} - 13.8\alpha - 17.5\beta)],$$

where all symbols with a stroke refer to the isomerized sample, γ is the total percentage of eleostearic acid lost in the process of alkaline isomerization.

In the present instance the content of diene acids after isomerization was 52.88%. In consequence, after deducting 4.05% of diene acids with conjugated double bonds, whose presence was found in the oil before isomerization, the linoleic acid represents 48.83%.

To sum up, the fatty-acid composition of catalpa oil is expressed by the figures in Table 1 where this composition is compared with the composition of tung and linseed oils.

In spite of the fundamental difference in the analytical methods the oleic acid content was found to be constant; as regards the other unsaturated acids, there was a marked difference in the figures found for the contents by chemical and spectrophotometric methods of analysis. The conventional chemical method of analysis based on the comparison of the iodine and thiocyanogen numbers gives approximately correct results only for oils which do not contain acids with conjugated double bonds. In the case of oils containing diene and triene acids with conjugated double bonds, preference must be given to spectrophotometric analysis.

From the data in Table 1 it is evident that, of the number of multiple unsaturated acids, whereas linseed oil (like the vast majority of vegetable oils) contains only acids with separate double bonds (linoleic and linolenic) and tung oil only contains acids with conjugated double bonds (eleostearic), both types of acid are found in catalpa oil; this is evidently the reason for the characteristic behavior of this oil, compared with other oils, during the process of film formation.

SUMMARY

1. The oil of Catalpa bignoniodes was investigated and its physical and chemical constants and fatty-acid composition established.

2. It was found that it contains an unusual combination of multiple unsaturated acids with separate double bonds (linoleic acid) and conjugated double bonds (diene acids, eleostearic acid).

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* In Russian.

SYNTHESIS OF THE METHYL ESTER OF THE RACEMIC ALKALOID OF DAURICINE

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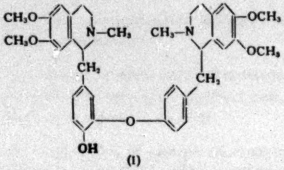
Dauricine (I) belongs to the class of so-called bicyclic lauric alkaloids. It was first isolated in 1927 by the Japanese investigators Kondo and Narita [1] from the stems and roots of Menispermum dohuricum D. C. (fam. Menispermaceae), found in Japan and Korea, and was later obtained from the forest lianas Menispermum canadense L., which grow in North America [2].



(I)

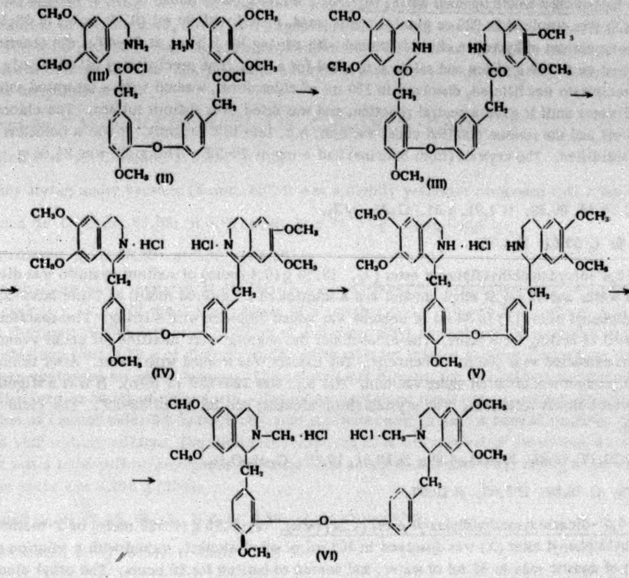
The structure of dauricine was proven as the result of a number of investigations [3,4]. To establish the structural formula of the alkaloid an attempt was made to synthesize it. The authors [4] obtained bis-[β-(6,7-dimethoxyphenylethylamide)]-2'-methoxy-5',4"-dicarboxymethyldiphenyl ester (III) which was then cyclized by the Bishler-Napiralsky method, hydrogenated, methylated, and subjected to the Hofmann degradation; the reactions were carried out without isolating the intermediate products.

The des-base which was obtained synthetically was identical with the base isolated by decomposing the methyl ester of the natural alkaloid.

The proposed formula found further confirmation as a result of the decomposition of the methyl ester of dauricine by metallic sodium in liquid ammonia [5]. *l*-1-(4'-methoxybenzyl)- and *l*-1-(4'-hydroxy-benzyl)-2-methyl-6,7-dimethoxy-1,2,3,4-tetrahydroxyisoquinolines were obtained; this not only determines the structure of the alkaloid but also indicates the *l*-configuration of both asymmetric carbon atoms of the molecule. The complete synthesis of the alkaloid has not yet been achieved. Works [6] have described the preparation of so-called "desoxydauricine" distinguished from the natural compound not only by the absence of the hydroxy group but also by the position of the estereal bond between the two benzyl radicals.

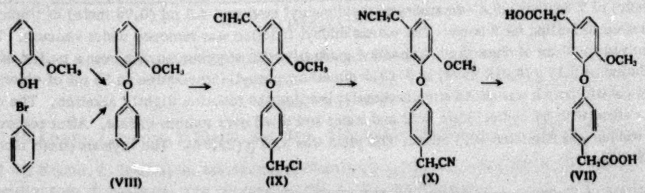
In recent years a considerable number of works have been published on the synthesis of bis-benzyl-tetrahydroisoquinoline alkaloids of cepharanthine and tetraidrine.

In 1952 Kondo [7] and his co-workers published the synthesis of cepharantine. In 1955, however, the same authors [8] rejected this work. In the same year an investigation was made on the structure of the desoxysigmagnoline molecule [9].



The dichloroanhydride of 2'-methoxy-5',4''-dicarboxymethyldiphenyl ester (II) was condensed with two molecules of homoveratrylamine and bis-[β-(6,7-dimethoxyphenylethylamide)]-2'-methoxy-5',4''-dicarboxymethyldiphenyl ester (III) obtained. The latter was cyclized by the Bishler-Napiralsky method with the formation of 2'-methoxy-5',4''-bis-(6,7-dimethoxy-3,4-dihydroisoquinoline)-dimethyl-diphenyl ester (IV) and then hydrogenated over platinic oxide until the corresponding tetrahydroisoquinoline derivative (V) was obtained. Methylation was carried out by the action of formalin in the presence of formic acid, compound (VI) being obtained. The initial substances for the synthesis of the dicarboxylic acid (VII) were guaiacol and bromobenzene which were condensed by Uhlmann's reaction.

The 2-methoxydiphenyl ester (VIII) was subjected to chloromethylation (IX) with subsequent replacement of the haloid by a nitro group (X) and saponification which leads to the formation of the 2-methoxy-5,4'-dicarboxymethylphenyl ester. The isolated acid (VII) showed no depression of the melting point in a mixed melt with the product obtained by condensing the methyl esters of 4-hydroxy- and 3-bromo-4-methoxy-phenylacetic acids.



EXPERIMENTAL

2-Methoxy-5,4'-dichloromethylphenyl ester [10] (IX). 31.75 g (0.16 mole) of the 2-methoxydiphenyl ester [11] (X) was dissolved in 225 cc glacial acetic acid, mixed with 30 ml (0.42 mole) of 38.4% formalin and a strong current of hydrogen chloride passed with stirring for 2 hours at 35-40°; the reaction mass was then poured on to 250 g of ice and allowed to stand for a day. The precipitated oil gradually solidified. The precipitate was filtered, dissolved in 150 ml of chloroform, washed with a saturated solution of alkali and water until it gave a neutral reaction, and was dried over sodium sulfate. The chloroform was distilled off and the residue distilled under vacuum, b.p. 180-182° (1 mm). It was a colorless oil which rapidly solidified. The crystals (from benzine) had a mp of 76-78°. The yield was 24.85 g (52.4%).

Found %: C 60.48, 60.23; H 4.91, 4.51. $C_{15}H_{14}O_2Cl_2$.

Calculated %: C 60.61; H 4.71.

2-Methoxy-5,4'-dicyanomethyldiphenyl ester (X). 19.75 g (0.4 mole) of sodium cyanide was dissolved in 34 ml of water and 62 ml of ethyl alcohol and a solution of 12 g (0.04 mole) of 2-methoxy-5,4'-dichloromethyl-diphenyl ester (IX) in 84 ml of acetone was added dropwise with stirring. The reaction mass was then heated to boiling for 3 hours. The alcohol and the acetone were distilled off under vacuum and the residue was extracted with 250 ml of benzene; The extract was washed with water. After removal of the benzene the product was distilled under vacuum. The b.p. was 220-230° (1 mm). It was a slightly yellowish liquid, which slowly solidified. The crystals (from alcohol) had an mp of 83-85°. The yield was 6.65 g (59.8%).

Found %: C 73.17, 73.31; H 5.11, 4.97; N 10.31, 10.06. $C_{17}H_{14}O_2N_2$.

Calculated %: C 73.38; H 5.03; N 10.07.

2-Methoxy-5,4'-dicarboxymethyldiphenyl ester [4,12] (VII). a) 6.95 g (0.025 mole) of 2-methoxy-5,4'-dicyanomethyldiphenyl ester (X) was dissolved in 100 ml of ethyl alcohol, mixed with a solution of 2.80 g (0.07 mole) of caustic soda in 35 ml of water, and heated to boiling for 15 hours. The ethyl alcohol was distilled off under vacuum and after extraction with chloroform the aqueous solution was acidified, with cooling, by hydrochloric acid until it gave an acid reaction with congo. A yellowish precipitate was obtained; it was separated and washed with water. The yield was 5.4 g (68.9%). After recrystallization from water to which animal charcoal was added, colorless crystals with an mp of 175-176° were obtained.

Found %: C 64.49, 64.78; H 5.11, 5.01. $C_{17}H_{16}O_6$.

Calculated %: C 64.57; H 5.00.

b) 20.7 g (0.08 mole) of the methyl ester of 3-bromo-4-methoxyphenylacetic acid, 13.32 g (0.065 mole) of the potassium salt of the methyl ester of 4-hydroxyphenylacetic acid, 1.5 g of copper catalyst, and 2 g of anhydrous copper sulfate were heated with periodic shaking for 2 hours at 140-150° and for 1.5 hours at 160-170°. The 2-methoxy-5,4'-dicarboxymethoxymethyl-diphenyl ester formed was isolated in the form of the free acid. After recrystallizing three times from water it had an mp of 176-177°. The yield was 1.4 g (6.82%).

Bis-[β-(3,4-dimethoxy)-phenylethylamide]-2'-methoxy-5',4''-dicarboxymethyldiphenyl ester [4] (III). 1.90 g (0.006 mole) of 2-methoxy-5,4'-dicarboxymethyldiphenyl ester and 4.3 ml (0.06 mole) of thionyl chloride were heated to boiling for 2 hours. The excess thionyl chloride was removed under vacuum. The residue was dissolved in 10 ml of chloroform and added gradually with vigorous stirring over a period of 30 minutes to a solution of 2.17 g (0.012 mole) of β-(3,4-dimethoxyphenyl)-ethylamine in 30 ml of chloroform. A 5% solution of caustic potash was added simultaneously, keeping the reaction slightly alkaline. The chloroform layer was washed with 5% hydrochloric acid and water and dried over sodium sulfate. After removing the solvent the residue was triturated with ether. The yield was 3.08 g (79.9%). The crystals (from alcohol) had a mp of 132-133°.

Dichlorhydrate of 2'-methoxy-5',4''-[bis-(6,7-dimethoxy-3,4-dihydroisoquinoline)] - dimethyldiphenyl ester (IV). 0.96 g (0.0015 mole) of bis-[β-(6,7-dimethoxyphenylethylamide)-2'-methoxy-5',4'']-dicarboxymethyl-diphenyl ester was dissolved in 7.3 ml of anhydrous chloroform and a solution of 1.53 g (0.0073 mole) of phosphorus pentachloride in 37 ml of anhydrous chloroform was added dropwise with stirring and cooling over a period of 30 minutes. The reaction mass was allowed to stand for 72 hours and was then heated for 1 hour to boiling. 50 cc of chloroform was added to the mixture which was washed with 30 ml of a 2% solution of caustic soda, 30 ml of 5% hydrochloric acid and water, and was then dried over sodium sulfate. The solid residue remaining after the distillation of the solvent was easily triturated with ether. The yield was 0.49 g (48.3%). The yellowish amorphous substance was reprecipitated from anhydrous ethyl alcohol by anhydrous ether.

Found %: C 64.80; H 6.55; N 3.71, 3.73. $C_{37}H_{40}O_6N_2Cl_2 \cdot C_2H_5OH$.

Calculated %: C 64.55; H 6.35; N 3.86.

After drying under vacuum (3 mm, 60°) it was a slightly yellowish compound with a mp of 174.5-176°.

Found %: C 65.22, 65.22; H 5.89, 6.09; N 3.94, 3.82. $C_{37}H_{40}O_6N_2Cl_2$.

Calculated %: C 65.39; H 5.89; N 4.12.

Chlorhydrate of 2'-methoxy-5',4''-[bis-(6,7-dimethoxy-1,2,3,4-tetrahydroisoquinoline)]-dimethyl--phenyl ester (V). 0.2 g of the dichlorhydrate of 2'-methoxy-5',4''-[bis-(6,7-dimethoxy-1,2-dihydroisoquinoline)]-dimethyl-diphenyl ester in 17 ml of anhydrous ethyl alcohol was hydrogenated over a platinum catalyst obtained from 0.19 g of platinic oxide. With constant shaking at room temperature the absorption of hydrogen continued for about 5 hours. The catalyst was filtered, the alcohol was distilled off, and the residue dissolved in 50 ml of chloroform. The solution obtained was washed in succession with 20 ml of a 2% solution of caustic soda, 5% hydrochloric acid and water until it gave a neutral reaction. The extract was dried with sodium sulfate. The substance remaining after the removal of the solvent was triturated in ether; it was a pale-yellow amorphous substance with an mp of 133-136° after drying under vacuum (6 mm, 60°). The yield was 0.096 g (50%).

Found %: C 68.54, 68.42; H 6.72, 6.80. $C_{37}H_{42}O_6N_2 \cdot HCl$.

Calculated %: C 68.51; H 6.65.

Dichlorhydrate of 2'-methoxy-5',4''-[bis-(N-methyl-6,7-dimethoxy-1,2,3,4-tetrahydroisoquinoline)]--dimethyldiphenyl ester (dichlorhydrate of o-methyl-dauricine) (VI). 0.09 g (0.000139 mole) of the chlorhydrate of 2'-methoxy-5',4''-[bis-(6,7-dimethoxy-1,2,3,4-tetrahydroisoquinoline)]-dimethyldiphenyl ester was dissolved in 40 ml of chloroform, shaken with 20 ml of a 10% solution of alkali and washed with water. The chloroform was distilled off under vacuum in a current of nitrogen and 0.04 ml (0.00055 mole) of 38.4% formalin in 0.12 ml (0.0026 mole) of 87.8% formic acid was added to the residue. The reaction mass was heated at 100° for 5 hours. 20 ml of benzene and a 5% solution of caustic soda were then added until an alkaline reaction was obtained. The extract was washed with water and dried over sodium sulfate. It was then partially distilled off under vacuum, the solvent was filtered and the benzene solution containing hydrogen chloride was acidified. The precipitate obtained was washed with anhydrous benzene by decanting and was then washed with anhydrous ether until it gave a neutral reaction. It was a yellowish substance, softening at 127.2° and with an mp of 129.5-132°. The yield was 0.05 g (52%).

Found %: C 65.53, 65.68; H 6.89, 6.67; N 3.88. $C_{39}H_{46}O_6N_2 \cdot 2HCl$.

Calculated %: C 65.82; H 6.76; N 3.93.

SUMMARY

The methyl ester of the racemic alkaloid of dauricine was synthesized.

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* Original Russian pagination. See C. B. translation.

THE QUANTITATIVE ANALYSIS OF COUMARIN BY THE ALKALI METHOD

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Coumarin forms the aromatic principle of many plants growing in the Soviet Union [1]. Methods for the quantitative analysis of coumarin in various types of raw material and products are still insufficiently developed. Of the published methods for the quantitative analysis of coumarin the most deserving of attention, since it is the simplest to perform, is the method based on the reaction with a 0.5 N solution of alkali with heating and subsequent titration of the excess alkali [2].

An experimental verification of this method showed that the results it gives are not sufficiently accurate. The errors in the results vary from 1.3 to 4.45%, the results obtained being on the low side. It was found that if instead of heating the reaction mixture it was allowed to stand for 10 minutes at room temperature and the excess alkali then titrated with a 0.1 N solution of hydrochloric acid, the errors in the results were reduced. The cause of the insufficient accuracy of the alkali method can be considered to be the inevitable hydrolysis of the alkaline salt of coumarinic acid (closure of the lactone ring, i.e. the formation of coumarin).

We studied the intensity of this process under the conditions of quantitative analysis and found that after only 5 minutes about 3% of coumarin was formed while after 16 hours relative equilibrium was established with the formation of 41% of the lactone.

When the salt of coumarinic acid is converted into the salt of coumaric acid hydrolysis is virtually eliminated. We succeeded in converting the cis-form of o-hydroxycinnamic acid (coumarinic) into its trans-form (coumaric) by Sen and Chakravarti's method who obtained nitrocoumaric acid from nitrocoumarin by heating the latter with aqueous alkali in the presence of mercuric oxide [3]. By a similar method, starting with coumarin we obtained coumaric acid. When we used an alcoholic solution of alkali for this purpose we obtained almost quantitative yields. It was found that by reacting the same reagents at room temperature the yield of coumaric acid was 70% after only 15 minutes. Conditions for the quantitative analysis of coumarin by the alkali method, giving more accurate results, were worked out on the basis of its conversion to the salt of coumaric acid.

EXPERIMENTAL

We used recrystallized coumarin with an mp of 70° for the experiments.

Determination of the intensity of formation of the lactone. A weighed sample of coumarin was dissolved in alcohol and made up to 100 ml with a further quantity of alcohol. 10 ml of this alcoholic solution was placed in each of a number of flasks to which 10 ml of a 0.5 N alcoholic solution of alkali was then added; after 10 minutes the excess alkali was titrated with a 0.1 N solution of hydrochloric acid. The titrated samples were left for various periods. The alkali formed by hydrolysis was titrated and the amount of lactone formed was calculated from the consumption of acid. The results are given in Table 1.

The preparation of coumaric acid from coumarin. 1 g of coumarin (1 mole) was dissolved in a solution of 1.20 g (4.20 moles) of caustic soda and 20 ml of water and 1.44 g (0.97 mole) of yellow mercuric oxide powder was added to it; the mixture was boiled for 1 hour. The cooled filtrate was acidified with dilute hydrochloric acid and the crystals formed were washed and dried. The yield was 1.05 g (94%). The compound melted at 208°.

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* Deceased.

When an alcoholic solution of alkali was used, all other conditions being equal, the yield of coumaric acid increased to 96.5%. When the reaction mixture was left at room temperature the yield of coumaric acid was on each occasion up to 70% after only 15 minutes.

TABLE 1

Duration of hydrolysis (in hours)	Amount of lactone (as %)
0.08	3.17
0.25	5.82
1	15.17
6	36.50
16	41.40
24	39.10

Determination of coumarin by the alkali method, converting it to the salt of coumaric acid. 0.1-0.3 g of coumarin (weighed accurately) was transferred to a 100 ml measuring flask and dissolved in 10 ml of alcohol. 0.1 g of yellow mercuric oxide powder was added to the solution; 10 ml of a 0.5 N alcoholic solution of caustic soda was then added after vigorous shaking. The mixture was left at room temperature for 15 minutes with frequent shaking, after which the contents of the flask were diluted with water up to the 100 ml mark, carefully shaken and filtered. The first batches of filtrate were discarded and 25 ml samples were selected from the subsequent batches. After titration of the excess alkali the solutions did not change color for 2 hours. The results obtained are given in Table 2.

TABLE 2

Weighed sample of coumarin (in g)	Amount of 0.1 N NaOH (in cc)	Coumarin found (in %)
0.1096	7.53	100.27
0.1204	8.26	100.17
0.3112	21.33	100.06

SUMMARY

1. When coumarin is analyzed quantitatively by Radcliff and Sharples' method, the reaction mixture should not be heated.

2. The intensity of hydrolysis of the alkali salt of coumarinic acid is fairly high: after 5 minutes the amount of lactone formed is 3%; relative equilibrium is established after 16 hours with the formation of about 41% of coumarin.

3. A method was developed for converting coumarin into coumaric acid, this method being used for the quantitative analysis of coumarin by the alkali method. The results obtained were fairly accurate.

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IN MEMORY OF YU. V. KORSHUN (1875-1951)

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On the 8th of August 1951 one of the senior Soviet chemists, the doctor of chemistry Professor Yury (Georgy) Vasilyevich Korshun, passed away in his 79th year. For more than 50 years (from 1899) he taught in the higher educational institutions of Kharkov (and partly in those of Dnepropetrovsk) as head of the chairs of Technical, General and Inorganic Chemistry. Almost the whole of his creative scientific activity took place within the walls of Kharkov University and, later, the Kharkov Polytechnic Institute. He had a fine training as an experimental chemist. A pupil of G. L. Lagermark and I. P. Osipov, he worked for several years in the best chemical laboratories of the day, those of Ciamician (Italy) and Ostwald (Leipzig), and others.

The extensive experimental work of Korshun was carried out with his pupils and co-workers, I. Trefilyev, K. V. Roll, A. I. Gunder, P. M. Bugai, N. M. Timashevskaya, and others. With very few exceptions, all this work was devoted to the study of one problem: that of pyrrole and its derivatives, which are compounds of great biological importance. Korshun was responsible for perfecting the method of obtaining very pure α,β-diacetopropionic ester, a fact which was of great importance for its wide use in the synthesis of new derivatives of pyrrole. He was the first to make a careful study of the reaction of α,β-diacetopropionic ester with amines, hydrazine and phenylhydrazine, and he studied the reaction mechanism of the synthesis of pyrrole derivatives by Hantzsch's method. He suggested new ways of synthesizing derivatives of pyrrole such as 2,5-dimethylpyrrole-3-carboxylic ester; 3,6-dimethyl-4,5-dihydropyridazine-4-monocarboxylic ester; 3,6-dimethyl-pyridazine-4-monocarboxylic ester, etc. He was the first to synthesize numerous derivatives of pyrrole such as 1,2,5-trimethylpyrrole-3-carboxylic ester; 2,5-dimethyl-1-ethylpyrrole-3-monocarboxylic ester, and the acids corresponding to these two compounds; 2,5-dimethyl-1-butylpyrrole-3-monocarboxylic ester; then α,α-dimethylfuran-β-monocarboxylic ester; 1-amino-2,5-dimethylpyrrole-3(4)-monocarboxylic ester; the methyl and ethyl esters of 1,2,3,5-tetramethylpyrrole-4-monocarboxylic acid; the methyl ester of β-methylamino-α-propenoic acid, etc. Korshun was the first to definitely establish the possibility of formation of a furan derivative also, by the action of ammonia on a 1,4-keto compound. In contrast to other investigators who worked with impure diacetopropionic ester, Korshun, by reacting the latter with phenylhydrazine, succeeded in obtaining a new compound, the diphenylhydrazone of diacetopropionic ester. As a result of the special investigations carried out by him he confirmed the correctness of Hantzsch's proposed mechanism of the derivatives of pyrrole from acetoacetic ester, ammonia and chloroacetone. During this work, by introducing chloroethyl and chloropropyl ketones in the reaction, the following compounds were synthesized: the methyl ester of 2,5-dimethylpyrrole-3-monocarboxylic acid, the methyl and ethyl esters of 2,3,5-trimethylpyrrole-4-monocarboxylic acid, the first trimethylpyrrole (2,3,5) and 2,5-dimethyl-3-ethylpyrrole-4-monocarboxylic ester.

In connection with the steric hindrance of adjacent methyl groups in the molecule of pyrrolecarboxylic acids, Korshun carried out extensive and varied physicochemical investigations (kinetic, thermochemical, refractometric, and on the absorption spectra in the ultraviolet region) on pyrrole and its derivatives with the main purpose of "forming an idea of the distribution of the forces of residual affinity in the pyrrole ring as a function of the presence of particular substituents." The constants of the rate of the bimolecular reactions of hydrolysis of more than 25 esters of various pyrrolemonocarboxylic- and pyrroledicarboxylic acids at different temperatures were determined. In this work many of the laws governing the influence of various groups (methyl, amino-, carbethoxy, etc.) on the constant of the rate of this reaction were established.

His spectrographic investigations were also very extensive. The absorption spectrum of pyrrole itself in the ultraviolet region was determined; the selective absorption of the ultraviolet rays of light by pyrrole which had been denied by other investigators, was discovered during this study of the absorption spectrum. The spectra of a large number of various pyrrole derivatives were determined and the influence on the absorption curves of various substituents (methyl, amino-, ureido-) at different positions in the ring was studied. On the basis of these data, Korshun put forward a number of interesting considerations with regard to the fine structure of pyrrole derivatives. He was also responsible for a considerable amount of research devoted to the development and application of the electronic theory to chemical processes. Especially distinguished by his ability to draw inferences and by his quick grasp of new trends in science, Korshun was one of the first to include courses on the electronic theory in the general chemistry syllabus and to consider chemical conversions on the basis of the latest current achievements of physical chemistry, the theory of electronic dissociation, the study of equilibrium, etc. He based his entire course of organic chemistry (1932) on the electronic theory. He was one of the first to attempt systematically to expound the whole course of organic chemistry on the basis of electronic representations, laying special emphasis on the idea of intramolecular polarization or ionization. To Korshun belongs the honor of developing original representations regarding the causes of the color of chemical compounds and the connection between color and molecular structure. The main tenet of his theory is that color is caused by the formation of ions representing free carbon-containing radicals. He also devoted a considerable amount of research to the physicochemical bases of qualitative analysis. Death overtook Korshun at a moment when (together with K.V. Roll) he was completing a major monograph on inorganic chemistry.

He was also extensively engaged in social activities. He was the organizer and the first director of the pharmaceutical technical schools of the Crimea (1922) and Dnepropetrovsk (1927), and an active member of Osoaviakhim. For many years he was an active member and one of the scientific directors of the Physicochemical Institute in Dnepropetrovsk (now the L. V. Pisarzhevsky Institute of Physical Chemistry of the Ukrainian Academy of Sciences). Korshun was the senior member of the D. I. Mendeleev society, an active participant at its meetings and congresses, and in its commissions and committees. In 1930 he was a member of the organizational committee for the VIth congress and one of the heads of the section on the "Nature of the Chemical Bond;" he edited the transactions of this congress. He reviewed many books and chemical theses (about 30) for candidate and doctorate degrees. They all bear witness to the thoroughness, conscientiousness and, in particular, adherence to principles which characterized his attitude to any work entrusted to him as a scientist. From 1947, Korshun was a member of the Communist Party of the Soviet Union.

As a sign of its recognition of his services to the Soviet fatherland, the government of the USSR bestowed on him the Order of the Red Star and the medal "For Valorous Labor in the Great Patriotic War, 1941-1945." Korshun will always be remembered by all his many pupils and acquaintances as a shining example of a Soviet scientist, a man of great creative energy who gave all his strength and exceptional capacities to the progress of our country.

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4. Synthesis of 1,2,5-trimethylpyrrole-4-monocarboxylic ester. J. Russ. Phys.-Chem. Soc., 35, 636 (1903) (together with I. Trefilyev).

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DISCUSSION

THE SECOND EDITION OF THE REPORT OF THE COMMITTEE OF THE ORGANIC CHEMISTRY SECTION OF THE ACADEMY OF SCIENCES USSR

"THE STATE OF THE THEORY OF CHEMICAL STRUCTURE IN ORGANIC CHEMISTRY" [1]

G. V. Chelintsev

I have had occasion to express my dissatisfaction with the first edition of this report [2]. I cannot remain silent on the second edition of the report as the "corrections and complementary material" introduced into it (page 4)* do not remove the fundamental discrepancy between the interpretation of the authors of the report and my theses [3], on which the report is based, concerning the practical fruitlessness, theoretical inconsistency and methodological fallaciousness of Ingold and Pauling's theory of mesomerism (resonance), its direct contradiction of Butlerov's tried theory of chemical structure and the necessity for a further development of chemical theory along Butlerov's lines. My remarks on the second edition are dictated not only by my obligation as the author of these theses to see that they are used, not to the detriment, but for the benefit of Soviet and world science, but also by my right to disclaim responsibility [10] for the interpretation placed upon the theses by the authors of the report (my silence might be mistaken as approval for the new version of the report). These remarks are all the more necessary because, owing to the great prestige of the committee, the fundamental misrepresentations by the authors of the report are being reproduced in other publications, particularly in textbooks [4].

Outwardly, the conception of the authors is a duplication of my own: a theory is proposed which is considered as a contemporary modification of Butlerov's theory of chemical structure and is opposed to the contemporary Ingold and Pauling theory of mesomerism. The difference consists in the fact that in place of my "new structural theory" a theory is advanced by the authors which is directly opposed to it and identical to the theory of mesomerism (the difference is purely one of nomenclature — in this connection see the verbatim report of my speeches at the All-Union Conference [2]). The paradoxical nature of the resulting conception has remained unnoticed by the authors because of a number of logical errors in their judgments.

One of the most serious errors of the authors is their interpretation of Butlerov's conception of two categories of mutual influence of atoms (page 7) in the sense of two types of spatial "displacements" in molecules (page 15). In actual fact Butlerov assigned the greatest significance to that variety of the mutual influence of atoms which is accompanied by their chemical change and which is reflected in contemporary (electronic) formulae of chemical structure as the distribution of the electrons between atoms, i.e. as the chemical composition of atoms in molecules (as a result of the yielding or acquisition or sharing of electrons, this composition is different from the electronic composition of free atoms); in consequence, the second — spatial — variety of the mutual influence of atoms includes only those electrostatic reactions of atoms having different electrical affinities in molecules which are transmitted along the chains of atoms by an inductive mechanism and determine the distribution of the electron density between the nuclei within the limits of the given distribution of electrons in atoms (in this sense it is possible to speak of the physical state of chemical structures). Affirming in every way the fictitiousness of structural-electronic formulae* — as true and well-defined expressions of the chemical structure of stable molecules, ions, bipolar ions, radicals, biradicals, complexes and unstable ones (pseudomeric with the former)** — the authors fail to notice that the mere replacement of concepts of resonance or disturbance by that of mutual influence (without the recognition of the truth of structural-electronic formulae***) is insufficient to convert the "mechanistic," "Machist," "idealistic," "common," "illusory" (pp. 45, 50 theory of Ingold and Pauling into the materialistic, quantum-mechanical, fruitful, contemporary modification of the thoery of chemical structure and mutual influence of Butlerov and Markovnikov. It is obvious, however, that the authors' theory (theory of mesomerism), by its method of multistructural expression**** not so much of the "actual nature of the molecule" (p. 10) as of its properties ("dynamic effects," p. 78) is a modification of Kekule's theory and not Butlerov's, and that it is, therefore, incorrect to represent it as such.

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*Here and subsequently, the references to page numbers, without an indication of the source, relate to the second edition of the report.

The second extremely serious error of the authors is their neglect of the chemically highly important principle of quantum mechanics concerning the saturability of bonds (p. 22), i.e. the capacity of an electron to pair with only one electron, to take part in the formation of not more than one covalent bond (in consequence of Pauli's principle). The new hypothesis of the authors (p. 32) concerning the nature of conjugation (single electrons remain in monoatomic orbits and "pair" with two electrons which are adjacent and have opposed spin, might have been considered as a hypothesis to the effect that only π-electrons do not obey this principle and as, therefore, not contradicting it as a whole, if the authors had confined themselves to the concept of π-conjugation and had left aside $\pi-\zeta$ and ζ-conjugations (pp. 103-116); by failing to do this, however, the authors in substance oppose this theory to the theory of quantum mechanics as a whole*****. It is evident that the new hypothesis of the authors can only be regarded as an attempt to explain the nature of π-conjugation by the polyradical structure of conjugated systems. At this point, however, a number of objections arise. The hexaradical formula of benzene [6] is not suitable for explaining the alternating polarity in the benzene ring, and while giving the appearance of explaining the causes of the instability of the penta-carbon analog of benzene [7], it cannot provide even this semblance of an explanation in cases of odd-numbered carbon analogs of butadiene and anthracene [8]. In addition, if it is taken into consideration that the paramagnetic properties of radicals are not removed either by the above-mentioned "pairings" of the electron with other electrons (for example, triphenylmethyl, p. 80), or by the even-numbered electronic composition of the molecules (biradicals, p. 83), it will be seen that the hexaradical structure of benzene does not agree with its diamagnetic properties. Finally, it must be pointed out that polyradical formulae are inapplicable in cases of π-conjugated systems of types of carbonate and guanidine ions, the cations of cyanine dyes, nitro and amino groups, etc., characterizing similarly conjugated systems of hydrocarbons by the coplanicity, by the straightening out of bonds over their length, by valance angles of the order of 120°, by the reduction in energy, etc. (this similarity makes it necessary to apply the hypothesis of π-conjugation in all instances). The fallaciousness of the authors' new hypothesis of conjugation is indicated by the fact that when they give factual data they do not use polyradical structures but Ingold's mesomeric formulae; this hypothesis only creates an illusion of a difference between the theory of the authors and Ingold and Pauling's theory of mesomerism.

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*The authors criticize Ingold and Pauling's theory for its use in the real sense of concepts of resonance or disturbances in fictitious structures expressed by structural-electronic formulae ("valence systems," "imaginary forms," pp. 42-50). The opinion expressed by the authors that "valence systems" were devised in quantum mechanics for convenience in calculations (pp. 42-43) is incomprehensible if only because it also applies to the Ingold formulae which were known long before these calculations originated.

**At the present time the reality of the usually listed unstable "intermediate products" of reactions is beyond doubt. The authors' interpretation of my conception of "electronic pseudomers" as the multistructural quality of molecules (p. 55) in no way corresponds to what I wrote in my "Essays" [3] and "Lectures" [9], to which the authors refer.

***Such a recognition is impossible because the mesomeric method of multistructural expression of the structure of the molecule (Ingold and Pauling's formulae) used by the authors in their theory, rests on the necessity to affirm the fictitiousness of "structures."

****The authors prefer to use the abbreviated notation of Ingold, which consists in taking one of the structures and marking the others on it by curved arrows. At the same time the authors recognize the equivalence of the theories and the formulae of Pauling and Ingold (pp. 48, 49, 118).

*****The fallaciousness of the conception of $\pi-\zeta$ and ζ-conjugations ("hyper-conjugation," "Nathan-Baker effect") has long been demonstrated [5]. The authors cannot abandon this concept because it is precisely in this sphere that the most important Soviet contribution to the theory of mesomerism, the affirmation of whose scientific value is the concern of the report, has been made.

The second attempt of the authors to retain Ingold and Pauling's formulae by reconciling the mesomeric conception of the fictitiousness of the formulae of chemical structure with Butlerov's conception of chemical structure has led, as might have been expected, only to a further accumulation of logical errors.

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* In Russian.

** Original Russian pagination. See C.B. Translation.

LETTER TO THE EDITOR

N. N. Suvorov

In the J. Am. Chem. Soc., 78, 5854 (1956) an article by M. Bullock and J. Hand on "The synthesis of some substituted indole-3-butyric acids" was published. Since the American authors do not refer to our previously-published work we consider it our duty to give the following information. As far back as 1949 we developed a simple and convenient method for obtaining γ-(3-indolyl) butyric acid, based on the use of Emil Fischer's reaction for the phenyl-hydrazone of the ethyl ester of δ-formylvalerianic acid with yields of up to 55% of the theoretical, with respect to the latter. The δ-formylvalerianic ester was obtained both by reducing the acyl chloride of δ-carbethoxyvalerianic acid by Rosenmund's method and from cyclohexanone via adipoin followed by splitting up with lead tetracetate. The method developed was protected by certificates of authorship under the title "A Method of Obtaining γ-(3-Indolyl) butyric Acid" in the name of N. N. Suvorov and V. K. Antonov, No. 77928 (priority from June 4, 1949), and N. N. Suvorov, V. K. Antonov, and G. M. Shagalova, No. 95779 (1951).

To study the relationship between the physiological activity and chemical structure we carried out a considerable amount of work on the synthesis of various substituted γ-(3-indolyl) butyric acids, whose influence on root formation was studied by R. Kh. Turetsky. The results of these were given in the form of four articles published in the Proceedings of the Academy of Sciences USSR in 1952-1955 and were abstracted in "Chemical Abstracts."[*] We must state that we were the first to describe the following compounds in chemical literature: 1-, 2-, 5- and 7-methyl-γ-(3-indolyl)butyric acids [N. N. Suvorov, V. K. Antonov, Proc. Acad. Sci. USSR, 84, 971 (1952)]; 1-, 2-, 5-phenyl- and 2-p-tolyl-γ-(3-indolyl)butyric acids [N. N. Suvorov, V. K. Antonov, E. M. Rokhlin, Proc. Acad. Sci. USSR, 91, 1345 (1953)]; 5-fluoro, 4-chloro-, 5-chloro-, 6-chloro, 7-chloro, 5-bromo and 5-iodo-γ-(3-indolyl)butyric acids [N. N. Suvorov, V. P. Mamaev, L. B. Shagalov, Proc. Acad. Sci. USSR, 93, 835 (1953)]; 5-methoxy-, 5-benzyloxy- 5-phenoxy-, 5-methoxy-7-chloro-γ-(3-indolyl)butyric acids [N. N. Suvorov, V. P. Mamaev, L. B. Shagalov, Proc. Acad. Sci. USSR, 101, 103 (1955)] and the ethyl esters of all three acids. The characteristics of these compounds as stimulators of root formation in experiments with bean grafts were given at the same time.

The synthesis of these compounds was carried out by the method we proposed in 1949 based on the example of γ-(3-indolyl)butyric acid. The same method was used by Bullock and Hand without any mention of our work. It must be mentioned that the yields which the American investigators obtained were considerably less than ours. For example, the yield given by Bullock and Hand for the ethyl ester of γ-(3-indolyl)butyric acid is 10.4% (compared with 35-55% in our work), 4 and 10% for the esters of 5- and 7-methylindolylbutyric acid, respectively (instead of 40 and 25% in our case), and 18% (instead of 27%) for the ethyl ester of 5-chloroindolylbutyric acid, etc.

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[*] Ch. A., 47, 3294 (1953); 48, 12078 (1954); 49, 1006 (1955); 50, 2543 (1956).

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